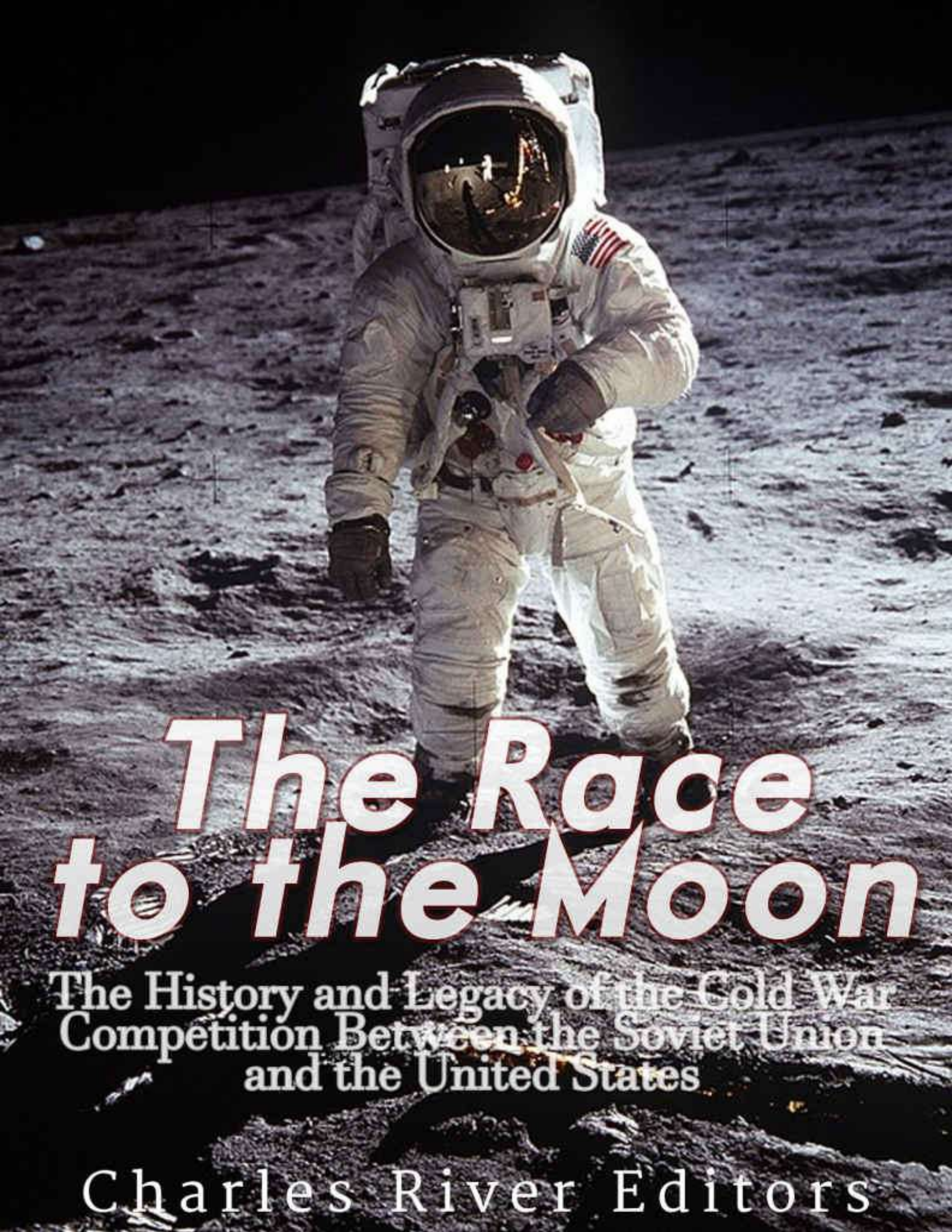
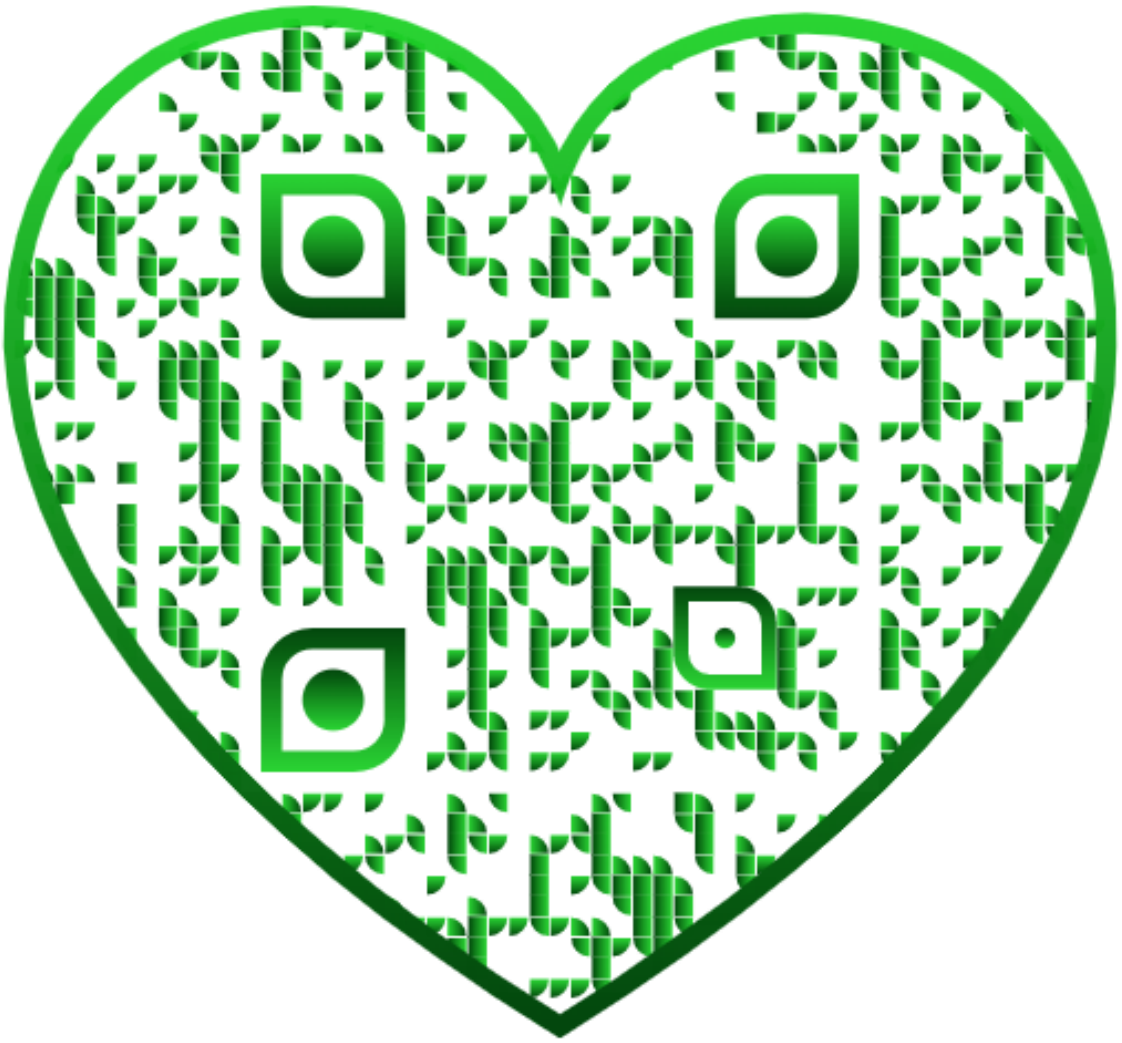


The Race to the Moon

The History and Legacy of the Cold War Competition Between the Soviet Union and the United States

Charles River Editors



The Race to the Moon: The History and Legacy of the Cold War Competition Between the Soviet Union and the United States

By Charles River Editors

Yuri Gagarin after becoming the first man in space

Introduction

The Russian Space Program

The Vostok I return capsule

Of all the goals the Bolshevik Revolution aimed to bring about, perhaps nowhere were Russian promises delivered on more than in the success of the Soviet Space program of the 1950s and 1960s. As a result of Russian innovation and technology, but also due to incredible drive to modernize and compete with the United States for world power, Russia was finally and triumphantly modernized in the eyes of her own people and the world. Neil deGrasse Tyson recognized the Soviet legacy in space in his *Space Chronicles*, citing the Soviets' "important measure[s] of space achievement: first spacewalk, longest spacewalk, first woman in space, first docking in space, first space station, longest time logged in space."[1]

In fact, the Soviet Union spent much of the 1950s leaving the United States in its dust (and rocket fuel). President Eisenhower and other Americans who could view Soviet rockets in the sky were justifiably worried that Soviet

satellites in orbit could soon be spying on them, or, even worse, dropping nuclear bombs on them. Dovetailing off their success developing intercontinental ballistic missiles, the Soviets were the first to make enormous advances in actual space exploration, and on the night of October 4, 1957, the Soviets prepared to launch “Object D” atop one of its R-7 rockets. As the world’s first ICBMs, R-7 rockets were built primarily to carry nuclear warheads, but “Object D” was a far different payload. “Object D” and the R-7 rocket launched from a hastily constructed launch pad, and within minutes it entered orbit. It took that object, now more famously known as Sputnik-1, about 90 minutes to complete its orbit around the Earth, speeding along at 18,000 miles per hour while transmitting a distinct beeping noise by radio.

Thanks to its transmission, and the bright mark it created in nighttime skies across the world, the world was already aware of the launch and orbit of Sputnik-1 before the Soviets formally announced the successful launch and orbit of their satellite. Naturally, the West wasn’t thrilled to learn about the Soviets’ launch of the first artificial object into Earth’s orbit. Sputnik-1 could be measured in inches, but that large rocket it was attached to could wreak havoc if equipped with a nuclear warhead. Moreover, if Americans could see Sputnik-1, they were justifiably worried Sputnik-1 could see them.

In 1960, when Eisenhower’s administration began planning and funding for the famous Apollo program that would land the first men on the Moon in 1969, the Soviet Union was already thinking further ahead, literally. In one of the worst kept secrets of the Space Race, the Soviet Union launched two probes, Korabl 4 and Korabl 5, toward Mars in October 1960.

Eventually, the Space Race produced some of the most iconic moments of the 20th century, including the landing of the first men on the Moon, and today, the race is widely viewed poignantly and fondly as a race to the Moon that culminated with Apollo 11 “winning” the race for the United States. In fact, it encompassed a much broader range of competition between the Soviet Union and the United States that affected everything from military technology to successfully launching satellites that could land on Mars or orbit other planets in the Solar System. Moreover, the notion that America “won” the Space Race at the end of the 1960s overlooks just how competitive the Space Race actually was in launching people into orbit, as well as the

major contributions the Space Race influenced in leading to today's International Space Station and continued space exploration.

The American Space Program

The insignia for the Apollo 1 mission

"There's always a possibility that you can have a catastrophic failure, of course; this can happen on any flight; it can happen on the last one as well as the first one. So, you just plan as best you can to take care of all these eventualities, and you get a well-trained crew and you go fly." - Gus Grissom, December 1966

The Apollo space program is the most famous and celebrated in American history, but the first successful landing of men on the Moon during Apollo 11 had complicated roots dating back over a decade, and it also involved one of NASA's most infamous tragedies. Landing on the Moon presented an ideal goal all on its own, but the government's urgency in designing the Apollo program was actually brought about by the Soviet Union, which spent much

of the 1950s leaving the United States in its dust (and rocket fuel). In 1957, at a time when people were concerned about communism and nuclear war, many Americans were dismayed by news that the Soviet Union was successfully launching satellites into orbit.

Among those concerned was President Dwight D. Eisenhower, whose space program was clearly lagging a few years behind the Soviets' space program. From 1959-1963, the United States worked toward putting satellites and humans into orbit via the Mercury program, but Eisenhower's administration was already designing plans for the Apollo program by 1960, a year before the first Russian orbited the Earth and two years before John Glenn became the first American to orbit the Earth.

On May 25, 1961, President John F. Kennedy addressed Congress and asked the nation to "commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth." Given America's inability to even put a man in orbit yet, this seemed like an overly ambitious goal, and it isn't even clear that Kennedy himself believed it possible; after all, he was reluctant to meet NASA Administrator James E. Webb's initial funding requests.

As Apollo 11's name suggests, there were actually a number of Apollo missions that came before, many of which included testing the rockets and different orbital and lunar modules in orbit. In fact, it wasn't until Apollo 8 that a manned vehicle was sent towards the Moon and back, and before that mission, the most famous Apollo mission was Apollo 1, albeit for all the wrong reasons.

There were no delusions regarding the dangers of manned space travel, but they were brought home on January 27, 1967, when all three astronauts were killed by a fire that ignited in the cabin during a launch rehearsal. To this day, there is still debate over what ignited the fire, but the disaster made clear that the modules being used by NASA had a series of fatal flaws. After the Apollo 1 tragedy, NASA changed its plans by first running a series of unmanned missions to test the Saturn rockets and the different modules throughout 1967 and early 1968. and it would not be until Apollo 7 launched about 20 months after the disaster that NASA dared to conduct another manned mission.

At 9:32 a.m. on July 16, 1969, time stood still throughout the world, as thousands converged on the Kennedy Space Center and millions tuned in on live television. At that instant, the first rumbles began to shake the ground, as a small spacecraft attached to the giant Saturn V rocket several hundred feet tall started lifting off. Quickly being propelled several thousand miles per hour, it takes just a few minutes to reach a speed of 15,000 miles per hour, and just a few more minutes to enter orbit at 18,000 miles per hour. Apollo 11 was on its way to a historic first landing on the Moon.

Apollo 11's trip to the Moon may have started on that day in 1969, but the journey had begun over a decade earlier as part of the Space Race between the United States and the Soviet Union. While landing on the Moon was a noble goal proposed as early as 1961 by President Kennedy, NASA and the nation as a whole moved with urgency simply to best the Soviet Union, which had spent the 1950s beating America to important space-related firsts, including launching the first satellite and cosmonaut in orbit. In fact, President Eisenhower's administration began the design for the Apollo program in 1960 in hopes of getting a head start to the Moon, despite the fact the plans originated a year before the first Russian cosmonaut, Yuri Gagarin, orbited the Earth and two years before John Glenn did.

Over the decade, NASA would spend tens of billions on the Apollo missions, the most expensive peacetime program in American history to that point, and even though Apollo 11 was only one of almost 20 Apollo missions, it was certainly the crown jewel. only one of nearly 20 Apollo missions conducted by NASA. And to make Apollo 11 a success, it would take nearly a decade of planning by government officials, hard work by NASA scientists, intense training by the astronauts, and several missions preceding Apollo 11. It also cost over $20 billion, making the Apollo program the most expensive peacetime program in American history at the time.

Americans sure felt the cost was worth it as they watched the first live shots of astronauts Neil Armstrong and Buzz Aldrin walking on the Moon. As he left his first footprint on the Moon, Armstrong transmitted one of the 20th century's most famous phrases: "That's one small step for man, one giant leap for mankind."

Apollo 12 successfully landed astronauts on the Moon just a few months after Apollo 11's successful mission. Apollo 12 was actually more successful than Apollo 11 from the standpoint of fulfilling the mission objectives, but it was naturally overshadowed since it did not come first.

Another reason Apollo 12 is mostly forgotten today can be credited to the dramatic and fateful Apollo 13 mission, which took twists and turns nobody could have predicted when it launched on April 11, 1970. Apollo 13's mission was to land on the Moon near the Fra Mauro highlands, which were hills that had somehow formed in the middle of a huge crater tens of miles wide. The mission was supposed to test for seismic activity and take samples to analyze the crater and try to find an explanation for the formation of the hills.

Of course, as is widely known today, Apollo 13 never made the landing. The ever-dependable Saturn V properly thrust Apollo 13 out of the Earth's orbit and toward the Moon, but two days into the voyage, the crew heard a loud bang. At first, the crew was not sure what had happened, leading Commander James Lovell to famously transmit to Mission Control, "Houston, we've had a problem." As it turned out, one of the main oxygen tanks had ruptured in the Service Module, causing a catastrophic failure. The Command/Service Module's fuel cells all shut down, leaving the command/Service Module to run on backup batteries. In other words, Apollo 13 was adrift between the Earth and the Moon with limited battery power.

With severely limited supplies and power, Apollo 13 shut down the Command/Service Module altogether, and the entire crew had to rely on camping out in the Lunar Module, which was only equipped to support two astronauts. The Moon landing was obviously out of the question, but Apollo 13 still had to orbit around the Moon to head back to Earth, a trip that would take four more days. Power and water were the two most critical shortages, forcing the crew to maintain the Lunar Module at low energy. The crew also had to worry about carbon dioxide building up and poisoning them, because the Lunar Module's system to remove carbon dioxide was designed to support two people for a few days, not three people for four days.

Once Apollo 13 rounded the Moon and headed back to Earth, the crew and Mission Control managed to restart the Command/Service Module, rerouting

power from the Lunar Module to the Command/Service Module. The crew also had to manually realign the spacecraft for reentry, as Lovell had done for Apollo 8. Before reentry, the Service Module was jettisoned from the spacecraft, and pictures of it were taken to see what went so terribly wrong. The crew then jettisoned the Lunar Module that had saved their lives, leaving it to burn up in the Earth’s atmosphere.

On the afternoon of April 17, Apollo 13’s Command Module made a nerve-wracking but successful reentry into Earth’s atmosphere, allowing Lovell to consider the mission a “successful failure.” Gene Kranz, the Lead Flight Controller at Mission Control, considered Apollo 13’s safe return to be "NASA's finest hour," and everyone at NASA breathed a heavy sigh of relief when Apollo 13’s crew made it back safely, but NASA began officially investigating what went wrong the day after splashdown, and for eight months, there were no Apollo missions, a lull about twice as long as the intervals between the previous missions.

Ultimately, Apollo 13’s close call did not deter NASA from continuing manned missions to the Moon. On January 31, 1971, Apollo 14 lifted off with the exact same mission Apollo 13 had. Apollo 13 likely would have faded into relative obscurity had it successfully completed its mission, because that has largely been Apollo 14’s fate. Apollo 14 successfully analyzed the Fra Mauro highlands and crater by spending over 30 hours on the Moon’s surface before returning without incident, but the harrowing mission that came before it has since been the subject of a critically acclaimed movie and remains well-known over 45 years later.

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The Origins of the Cold War Space Race

Today the Space Race is remembered as a battle of ideology and technology between the Communist Soviet Union and the democratic United States, a centerpiece of the Cold War that dominated geopolitics for the second half of the 20th century. But the origins of the Space Race could not be found anywhere near Moscow or Washington, D.C.

1945 was the year World War II ended in Europe, with the Soviets and Americans engaged in a wholly different race: the race to Berlin. As Hitler's Nazis were being pushed back in both the East and West, the war's end was imminent, but the Nazis had no intention of going down without a fight. From 1944-1945, the Nazis began pummeling Great Britain with one of the most technologically advanced weapons ever created: the V-2 rocket.

Almost all of Nazi Germany's intellectual resources were devoted to military research during World War II, and advanced bombs in the form of long-range missiles and rockets became the focus of German scientists. Throughout the 1930s and into the early 1940s, the Nazis focused on the creation of a long-range ballistic missile. This research culminated in 1942 with the creation of the German V-2 rocket, the world's first ballistic missile, and later the first man-made object to be intentionally launched into outer space.

On October 3rd, 1942, the first V-2 rocket was tested, and it successfully entered outer space. While this was the dawn of the era of space travel, it was bombs that travelled through space in 1942, not people. The V-2 rocket wielded devastating results, particularly in Belgium and Britain, as these first ballistic missiles were used to bomb sites in London and Antwerp remotely, killing thousands of innocent civilians. The rocket's supersonic speed made it impossible for Allied forces to quickly detect, let alone stop.

Initially, the V-2 rocket encountered accuracy problems, as projecting where the rocket would land presented an enormous issue for German scientists. At the time, however, the men launching the rockets weren't too concerned about indiscriminate bombing, so long as they hit Allied targets.

When World War II was over, the United States and Soviet Union turned

their attention from Nazi Germany to each other. Both sides began secretly working to recruit the Nazi scientists involved with designing the V-2 rockets and bring them to Russia and America, in effect giving them immunity from prosecution for war crimes. One of these Nazi scientists, Wernher von Braun, was instrumental in the development of V-2 rockets for the Nazis, and he was brought to America by the Truman Administration. Von Braun became more important than any American in the development of American rockets. In the 1950s he helped design the Jupiter class of rockets. When the United States fell behind the Soviets in the Space Race, they relied more heavily on von Braun's designs. When Apollo 11 lifted off into space, it was riding atop a Saturn V rocket designed by von Braun.

Von Braun

With the end of the war, American and Soviet scientists gained access to the plans and specifications of the German V-2 rocket. The two sides now had their hands on important, sensitive research, made all the more necessary due to the fact that their technology was well behind the Nazis' at the end of the war.

Even before the war, American scientists were experimenting with rocketry. Unlike the Germans, however, the Americans were unable to create a rocket that propelled into outer space. Regardless, the nation's scientists

were actually the first to create a liquid-fueled rocket in Auburn, Massachusetts, in 1926. Four years later, the American Interplanetary Society was created in New York City, to promote the study of space travel.

Throughout the war, however, neither the Americans nor the Soviets were able to match the power of German ingenuity when it came to space exploration. With the war's end, the Americans and the Soviets seized the V-2 rocket components and specifications, sending them home to their respective laboratories for additional study. The United States harnessed the intellectual might of nearly 700 German scientists through Truman's top secret "Operation Paperclip", which stealthily relocated the scientists into America.

While the U.S. successfully brought in Nazi scientists, the proximity of Germany to Russia helped ensure it would be the Soviet Union that took much of the Nazi infrastructure left behind. Because the Soviets occupied East Germany, where much of the V-2 program was developed, it was able to capture and utilize the rocketry facilities. Quietly, the two nations began a race into space, using German advances as a springboard.

With these German resources in hand, both the Americans and the Soviets were able to project their own rockets into outer space within just a few years. Although Sputnik 1 will forever be celebrated as the first satellite to orbit Earth, America beat the Soviets in the race to project *something* into space. On March 22nd, 1946, the United States became the second nation in the world to propel an object into outer space when it successfully launched an exact replica of a German V-2 rocket outside of the earth's atmosphere. Later that year, the U.S. attached a motion picture camera to a V-2 and was able to take the first photographs and videos of the Earth from outer space. In 1947, the U.S. made great advances in using rocketry to transport living beings into space when in launched fruit flies into space aboard a V-2 rocket. Though they were just flies, this marked the first time a living organism travelled outside the earth's atmosphere.

Across the world, the Soviets were not so quick to enter space. The U.S. had the benefit not only of German scientists, but also of having German V-2 rockets on hand. It was thus much easier to copy the V-2 in America than in the Soviet Union, which only had specifications, blueprints and building

materials. During the rest of the 1940s, the Soviets were playing catch-up on a variety of fronts, including the space and arms races. While the U.S. had detonated a nuclear bomb in 1945, the Soviets were not able to achieve that milestone until 1949, and while the U.S. now had a workable ballistic missile in the V-2, the Soviets would not have their own until the mid-1950s. Across the Soviet sphere, there was an intellectual disdain for space travel, which was considered impractical and irrelevant to the aims of the country, but space technology was vital for reaching military superiority or at least military equality with America.

In early 1951, the United States established "Project MX-1593", a top secret and heavily funded program that became part of the U.S. Air Force. The purpose of MX-1593 was to create an intercontinental ballistic missile capable of carrying a nuclear warhead. The aim was, obviously, to establish a system allowing the U.S. to target a Soviet site anywhere in the world remotely.

With Project MX-1593, America seemed to hold the advantage in creating an ICBM, and von Braun had been part of the Nazi team that envisioned rockets that could bomb the East Coast of the United States itself, which would have required an intercontinental ballistic missile (ICBM). However, the Germans were unable to achieve this goal. Since von Braun had already begun the research for an ICBM, the Americans seemed positioned to make enormous progress.

However, it was the Soviets who were first to create an ICBM. On August 21st, 1957, the Soviets launched the R-7 Semyorka, which was the world's first intercontinental ballistic missile. Work on the project began in 1953, while the American program had begun two years prior, but the Soviets were nonetheless able to complete the mission earlier. The first successful test launch in 1957 allowed the missile to travel nearly 4,000 miles.

Soviet eagerness to develop an ICBM was fueled in part by the superiority of the U.S. Air Force, which was larger and more advanced than the Soviet arsenal. Thus, the USSR felt it needed alternative ways to deliver nuclear warheads into American territory if its nuclear arsenal were to remain strategically relevant and military equity or superiority was to be achieved. The creation of the ICBM essentially negated the superiority of the U.S. Air

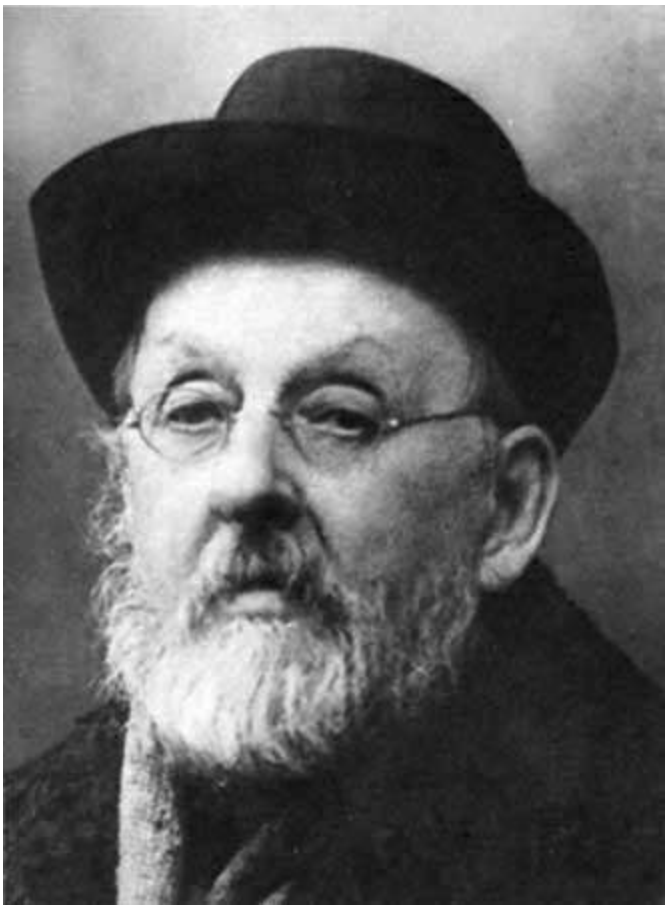
Force, erasing all strategic edges the U.S. held over the USSR. At the same time, with this success, the Soviets opened nearly a decade of dominance of space exploration, which culminated in the launching of the world's first human being into outer space.

The Origins of the Russian Space Program

In 1721, Russia's Peter the Great began a 43 year reign over a Russia he was determined to bring into modern times. Embarking on a tour of modern capitals across Europe, he instituted a forced modernization of his own country that included building programs, increased taxation, and the construction of a modern capital and namesake, St. Petersburg. One of Peter's greatest goals was the modernization of the Russian army, both in its organization and in the technology of its weaponry. Advances in weapons technology, he promised, would provide Russia with the edge it needed to vault itself into modernity and catch up to the nations of Western Europe. Peter the Great even established Russia's first Academy of the Sciences in St. Petersburg, though the lack of Russian thinkers meant that, for the moment, the academy was staffed with scientists from Sweden and Germany.[2] Russia's future rulers, whether tsars or socialists, would continue to promise that technology and science would secure Russia's place amongst the nations.

Peter the Great

Konstantin Tsiolkovsky, born in 1857, was the son of a Polish deportee to Siberia. A mathematician, inventor, and thinker, he is credited with the Tsiolkovsky formula which "established the relationships among rocket speed, the speed of the gas at exit, and the mass of the rocket and its propellant [and is] the basis of much of the spacecraft engineering."[3]



Tsiolkovsky

Looking for the earliest mention of manned space flight in Russian history, one finds a story recorded by Brian Harvey in his *Soviet and Russian Lunar Exploration*. He tells of a Soviet scientist, Mikhail Tikhonravov, who suggested a manned space flight in the pages of a children's magazine, which attracted the attention of both foreign governments and his own: "We do not have long to wait. We can assume that the bold dream of Tsiolkovsky will be realized within the next ten to fifteen years. All of you will become witnesses to this and some of you may even be participants in unprecedented journeys,"[4] he wrote to his audience of Soviet youth. Harvey writes of the early and little known collaboration of Tikhonravov and a then little known Russian military scientist by the name of Sergei Korolev, who would become the Soviets' chief designer and the mind behind much of the Soviet space achievement for almost two decades.

Korolev

The Soviet space program started in earnest with the work of three scientists in the 1930s, but it would be a rough road to the earliest successes. Sergei Korolev, a Ukrainian technical student, along with fellow scientists, was recruited by the Soviet government in the early 1930s to incorporate their experiments with rockets, propelled by Glushko engines into the higher reaches, "where they could see the sky turn deep violet."[5] These early flights were conducted with balloons - either unmanned or manned, such as the flight of USSR I, and allowed Soviet scientists to collect information about air quality, the appearance of the sun, and the reaction of their craft to cosmic rays that proved important for later missions.[6] During Stalin's purge of the Soviet generals, many of these scientists became suspect, and some, including Korolev, spent time in prison camps. Korolev was a victim of one of hundreds of Stalinist purges when he and a list of 74 additional Russian scientists were accused and isolated for purging after the usual Stalinist show trial. The charges that led to Korolev's conviction consisted of utterly ludicrous "Crimes in the field of a new technology."[7]

Korolev was said to have shared the experience of his trial and conviction with two cosmonauts, Yuri Gagarin and Alexei Leonov, many years later. He told of being questioned by three Soviet officials after being arrested

without warning at his home in 1938. His trial, according to Korolev, lasted only one minute, after he was required to read off a list of three specific charges. Korolev denied the charges.[8] Korolev, unlike many others, was not slated for immediate execution, but was given a ten year sentence in a forced labor camp where he endured among other things, a broken jaw that never healed correctly. After serving only a few months of his sentence, the needs for the Russians to develop better weaponry for WWII meant that Korolev was released. He spent over six months attempting to return to Moscow in the icy, Russian winter and upon his return, he was allowed only to live in a dormitory with fellow scientists and weapons developers, not to return home to his wife and children.[9]

Gagarin

Though Korolev understood well that the rocket research he performed was targeted for pursuit of intercontinental ballistic missile launchers, he “always

designed the rocket with a secondary purpose in mind: to open the door to space travel."[10] Khrushchev was leading the Soviets in an aggressive and public push for Intercontinental Ballistic Missile development. As tensions between the U.S. and the U.S.S.R continued to escalate, the countries were in competition in weapons development and in the race for world leadership. In *Space Travel: A History*, Wernher Von Braun argues that the United States' more sophisticated development of military weaponry was what actually caused the Soviets to appear to leap ahead with the eventual launch of Sputnik. While the U.S. concentrated on the development of smaller warheads that could be launched by ICBMs, the Soviets "went ahead and developed the massive rockets needed to carry its primitive bombs ─the same vehicles that later gave it a significant advantage in space exploration."[11] The argument over whether or not the Soviets were actually ahead or only appeared ahead of the rest of the world in the 1950s and 1960s space program is one for historians today, but in the months leading to Sputnik's launch, the rivalry was anything but theoretical. In August of 1957, the Soviet's TASS news agency delivered this message about their military superiority and potential for dominance: "A few days ago a super long range, intercontinental multistage ballistic missile was launched…Covering an enormous distance in a short time, the missile hit the assigned region. The results obtained show that there is the possibility of launching missiles into any region of the terrestrial globe."[12]

Von Braun

William Burrows, a professor of journalism and feature writer on space and aviation, explains Nikita Khrushchev's motives and his support for the burgeoning Soviet space program as political, and not merely strategic. As the Soviet Union continued to struggle from behind to catch her rivals in the west, and America's new president, John F. Kennedy, began calling for further exploration, "Khrushchev had become convinced that excelling in space (or seeming to) not only had immense propaganda values at home and abroad, but was relatively cheap for what it bought. And what it bought was the appearance of strength; a defensive mirage. Technology was the embodiment of socialism's triumph over nature and had long been the state religion. But its most important icon was no longer the tractor, the hydroelectric plant, or even the hydrogen bomb. It was the rocket."[13]

Khrushchev

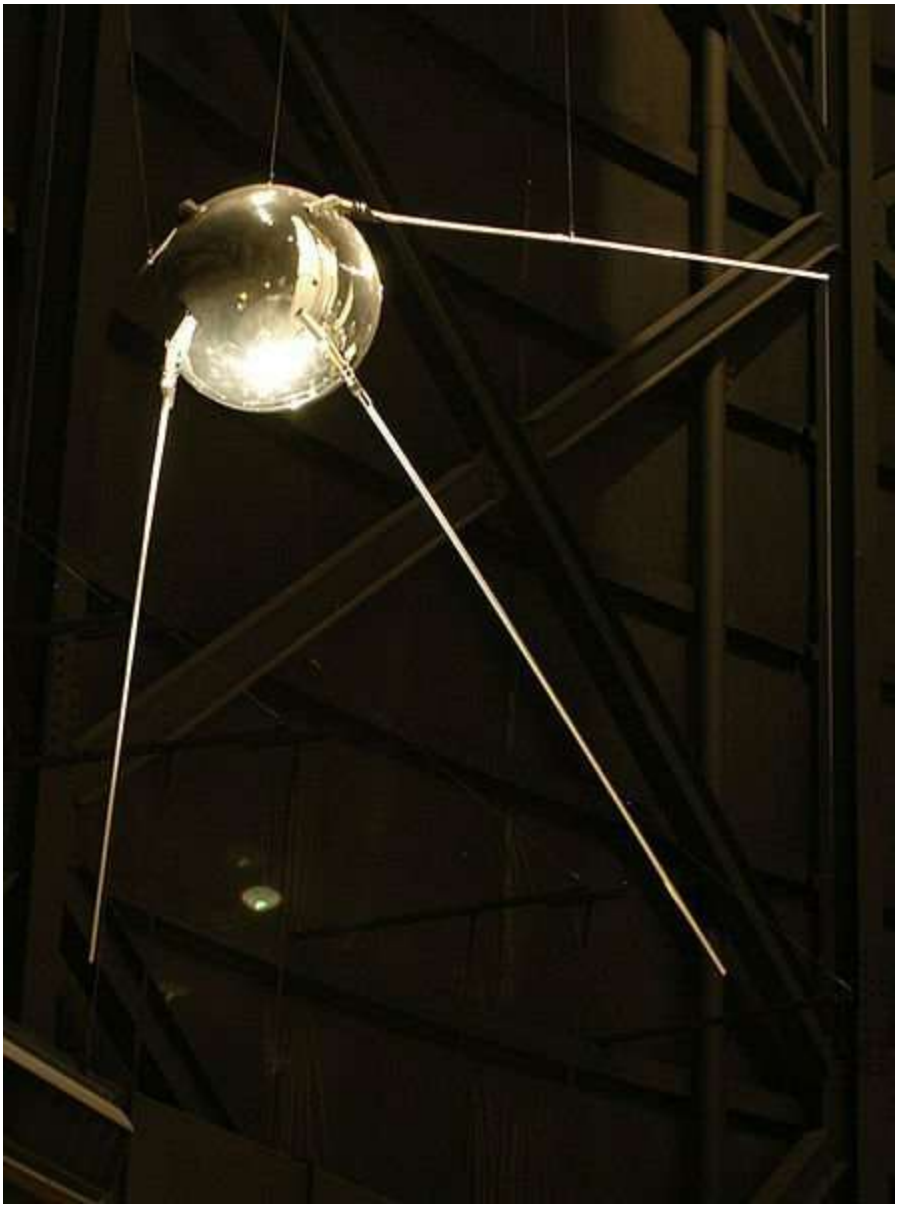
Soviet Premier Khrushchev's rocky rise to power had included a close call with an ouster in the summer of 1957. Khrushchev, it was felt by several members of the Presidium, had been rash in his commentary regarding the

United States' ability to keep up with the Soviets in agricultural production: "We will bury you!," he had famously declared in reference to Soviet agricultural output goals. They mockingly accused him of having "become the expert on everything- from agriculture to science to culture."[14] He was, in fact, ousted as first secretary of the party, but in a precedent-setting turn of events, used his support amongst members of the central committee to overturn the vote of the Presidium.[15]

Khrushchev knew that to maintain power he would need the continued support of many on the Central Committee. This support could be maintained, he believed, with specific accomplishments in the fields of weapon's development and accomplishments in space. Khrushchev preferred the former, but competition with the United States in any form in those Cold War days was worthy enough of his attention and of funding and support.

Mathew Brzezinski records the story of Khrushchev's visit to Korolev's design laboratories in 1956. Here, Korolev revealed the potential of the rockets in development, as well as the missiles they would launch. Khrushchev stared at a classified map that revealed which countries rockets and missiles already developed and tested could strike. "How many warheads would be needed to destroy England? Have you calculated that?"[16] The answer came back with a claim and a confidence level that astonished Khrushchev: "Five would be enough to crush defenses and disrupt communications and transportation, not to mention the destruction of major cities."[17] Khrushchev was stunned and at first a bit skeptical. The V-2 rocket, developed at the end of WWII by German scientists and used at the end of the war, was Khrushchev's ideas of the ultimate deadly weapon. The fact that the Americans were attempting to develop technology with Wernher Von Braun, one of the V-2's creators, had long made the Soviets nervous. Now, an incredulous Khrushchev was told that the R-7 could go "four times faster and forty times further than the original V-2."[18] Trying to grasp its speed, Khrushchev tried to gain perspective, asking how long it would take the rocket to fly from Moscow to Kiev, a three hour flight for conventional planes. The answer: one minute.[19]

Sputnik



A replica of Sputnik

Eventually, the successful launch of a Soviet satellite and the ensuing space race with the United States brought the rivalry between the United States and the Soviets to the attention of the world, but at first, the Soviet government seemed to merely tolerate what seemed like a “hobby” of the scientists working on launchers for ICBMs. Sergei Korolev, however, successfully convinced Khrushchev that the Soviets could launch a successful satellite, amounting to “single-handedly wav[ing] the opening flag in the space

race."[20]

It was during the 1956 meeting that Korolev made his pitch for what would become known as Sputnik. At the conclusion of Khrushchev's tour of the design laboratories, Korolev revealed his project, but the lack of understanding of what a satellite was and what its successful launch would represent on behalf of Khrushchev and other Soviet officials was clear to Korolev. He convinced Khrushchev to allow him to move ahead with Sputnik's development on two grounds: that an R-7 capable of launching a satellite was also capable of launching a warhead, and that the United States was in process of developing a satellite as well. Korolev persuaded the Soviet leader that Russia had a chance to beat them, meaning Khrushchev could get what he wanted in significant weapons development as well as have the chance to beat the Americans at something Korolev seemed to think was significant. His answer came back, "If the main task [weapons development] doesn't suffer, do it."[21]

After several experimental rockets, Korolev and others became convinced they could create a rocket launcher powerful enough to put a satellite into orbit. The R-7 that had been introduced to Khrushchev during the design bureau visit represented, as Korolev put it, not the past and present of Soviet rocketry but the future.[22] In hindsight, according to Brzezinski at least, Korolev had overpromised in his attempt to convince Khrushchev to allow development of the satellite project to move forward, because the R-7 rocket that had been so proudly revealed as the "future" of Soviet military dominance was "an illusion, little more than a ten-story-tall modeler's toy. The real prototype was nowhere near ready."[23]

Nonetheless, Soviet engineers and designers continued their labor, readying several satellite candidates at one time. As time for the launch drew closer, it was determined that the more complicated satellite that some had hoped would be ready to launch needed to be put on hold. The "ton-and-a-half cone studded with antennas"[24] would be put on hold (and later launched as Sputnik 3). In the meantime, the "polished ball" that author William E. Burrows calls "Korolev's last choice" would be readied for launch.

Sputnik was launched into space just before midnight on October 4, 1957, and the R-7 rocket launcher was successful in putting the "preliminary

satellite”[25] into orbit. Korolev took a moment to speak with his fellow scientists, saying, “Today, the dreams of the best sons of mankind have come true. The assault on space has begun.”[26] The news was greeted by the world with shock and surprise; there had been consistent rumors of Soviet attempts to ready for a launch into space, but most Americans assumed they were still a long ways off from success. The Soviets were “gently” criticized by members of the scientific community of five nations that had gathered in Washington D.C. in 1957, to which the Soviets responded by “saying they considered it unseemly to ‘boast’ about experiments until they were complete. ‘We will not cackle until we have laid our egg.’” In the midst of the gathering of some of the world’s most formidable scientists, the news arrived that a Russian satellite was circling ahead. The majority of the scientists present seemed surprised but pleased at the news, and congratulations were given to the Soviets, who were suddenly the celebrities of the event. [27]

The importance of Sputnik in both Soviet history and the history of space exploration in general cannot be overstated. Not only did Sputnik encourage Soviet pride in having beaten the Americans to an important milestone, it “inaugurated the first triumphant decade of Soviet space exploration, as one after another, Soviet space exploits inscribed a new glorious cosmic future into the fabric of a popular imagination. A row of hero cosmonauts circle the earth in increasingly ambitious ventures in their Vostok and Voskhod spaceships.”[28]

The satellite itself, weighing 184 pounds, was surprisingly simple.[29] Korolev led the team of scientists and engineers to create Sputnik, “a sphere of aluminum alloys with four spring loaded whip antennas and two battery-powered radio transmitters” …it was fitted “within a pointed metal nose cone.”[30] In order to ensure the satellite was constructed to his specifications, Korolev not only participated in but directly supervised construction and launch, living on site “halfway between the rocket assembly building and the R-7 launchpad.”[31]

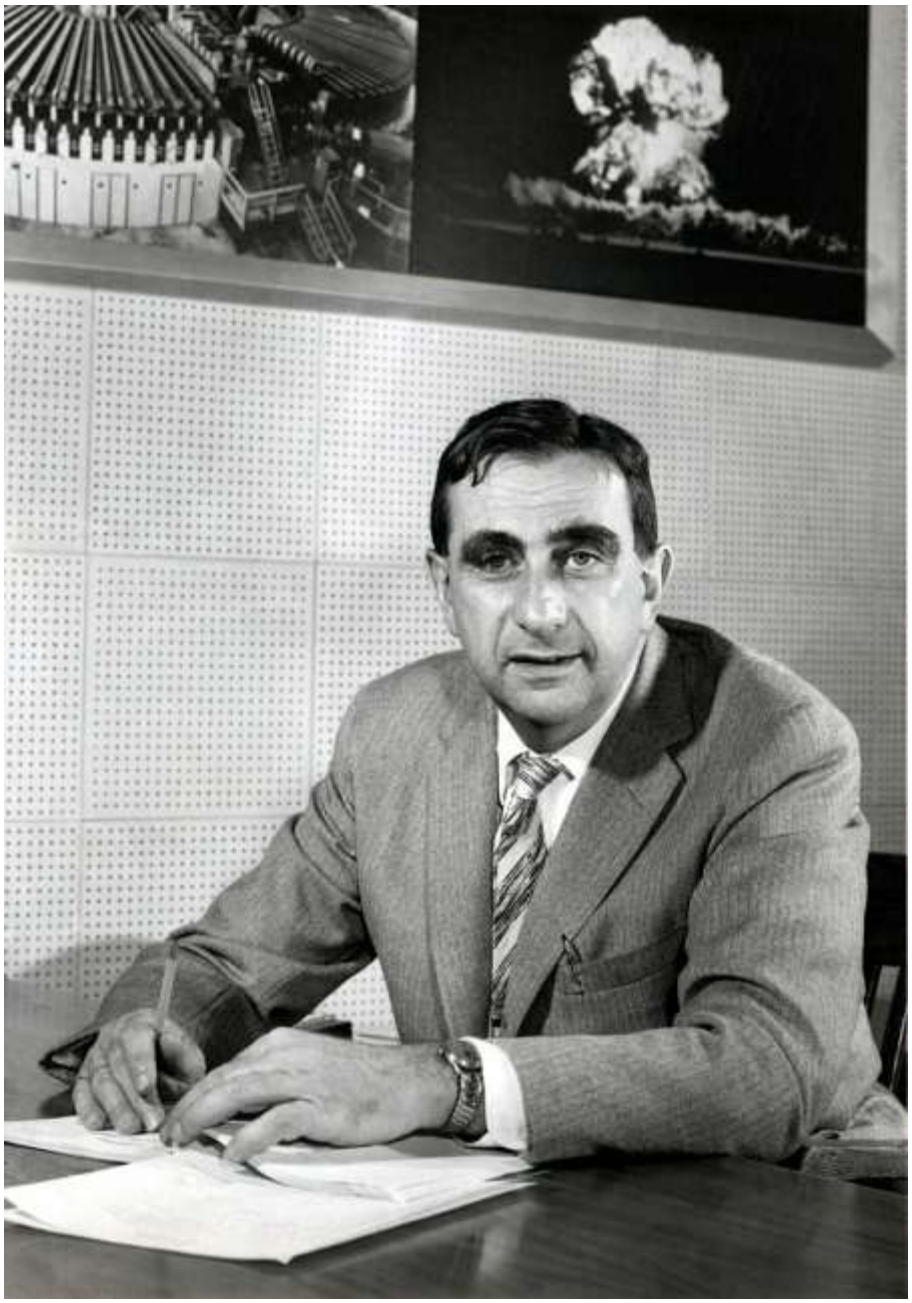
Pravda reported on October 5th, “The successful launching of the first man-made earth satellite makes an important contribution to the treasure-house of world science and culture…Artificial earth satellites will pave the way for

interplanetary travel and apparently our contemporaries will witness how the freed and conscientious labor of the people of the new socialist society makes the most daring dreams of mankind a reality."[32]

Sputnik itself was derided by Eisenhower as nothing more than "one small ball in the air,"[33] but impressively, the Soviets had completed construction of the satellite in three months once Khrushchev had given the green light to the project. The ball itself was made of aluminum, polished and surrounding a battery pack that emitted a distinctive beep that would allow both U.S. and Soviet scientists to confirm its orbit.[34] It would orbit the earth at a speed of over 18,000 miles per hour, which meant one elliptical revolution took about 96 minutes.[35]

Historians agree that the American response to the Soviet's initial space success in Sputnik was generally dismay, and in some circles, shock. Americans were able not only to hear Sputnik's beeps over the radio but see the satellite in the night sky over the United States. A photograph of two young American boys, backs to the camera, looking up at the shining Russian satellite from behind a railing is the opening image to Paul Dickson's *Sputnik: The Shock of the Century*.[36] Edwin Marcus's cartoon shows a rudely awakened Uncle Sam in his nightshirt, sitting up in a bed called "complacency" with Sputnik beeping loudly from the sky outside his bedroom window. The caption below asks the simple but significant question, "Awake at Last?"[37]

The country reacted with fear, partly led by those who appeared to have reason to know. Edward Teller, inventor of the hydrogen bomb, said that the launch of Sputnik meant that the U.S. "had lost a battle more important and greater than Pearl Harbor."[38] Though later historians would come to discount the military significance of Sputnik (since the R-7 launcher used to put Sputnik into orbit was not capable of successfully launching ICBMs), one could safely say that "there was a sudden crisis of confidence in American technology, values, politics, and the military."[39]



Teller

Khrushchev took full advantage of the surprise, pointing out, “People of the whole world are pointing to the satellite. They are saying that the U.S. has been beaten.”[40] Should the United States have been as surprised as with the public claims that the Soviets had been making? Perhaps not, but “Americans, who had become accustomed to laughing at Russia’s technological efforts…suddenly [found] themselves in the uncomfortable position of second place in a two-horse race.”[41] The suspicion and fear

would continue with each Soviet triumph.

Though there is little debate about the immediate American response to Sputnik's launch, much has been written about Sputnik's actual significance and of the success of the Russian space program over time. Many Americans viewed Sputnik as a sign that the United States had fallen behind militarily, while others argued that the country had fallen behind in the larger context of scientific inquiry. Some historians, however, have come to the conclusion that while the launch of Sputnik took the American science community by surprise, it did not mean that the Soviets had achieved military superiority of any kind. In fact, author Harry Hopkinson claims Sputnik functioned as less of an example of Soviet military strength and more as a strategic bluff on the part of Khrushchev, a scare tactic that the Soviet leader employed to help establish the United States' acceptance of a "peaceful coexistence" with a Soviet Union that was actually far weaker than it was purported to be.[42]

In their book *Moon Shot: The Inside Story of America's Race to the Moon*, Alan Shepard and Deke Slayton argue that the Eisenhower administration had ignored warnings and signs that the Soviets would reach space before the United States. Their claim includes charges that Wernher von Braun, a German scientist recruited by the American military after the defeat of the Nazis, asked for permission to launch a project of his own design, a satellite known as Missile 29. If so, the reasons for such a refusal are still widely debated. It's possible Eisenhower wanted an American and not a German scientist to get credit for the initial launch, and some think the administration demanded that the first American satellite be disassociated with military efforts and seen as purely scientific. Whatever the case, Eisenhower ordered Braun's project be placed in storage, ensuring the Russians had "an open door and a free ride to lead the world into tomorrow."[43]

Debates over geopolitical context aside, the launch of Sputnik I is largely hailed as the opening moment of the true "Space Race" not only because of the fame and fear inspired by the launch but also because its purpose was not entirely one of military value. While the Sputnik satellite indicated the Soviets had significant military advantages in potentially weaponizing space, Sputnik's value was not exclusively military. Had something like Sputnik-1 been America's goal in 1957, it very likely could have accomplished this

important first. Von Braun had successfully designed the Jupiter-C rocket by 1956, which could have allowed the United States to launch a satellite like Sputnik-1 into space a year before the Soviets did, but at the time, however, the technology was being designed for use as missiles. In response to Sputnik-1, Eisenhower quickly ordered an attempt to put a satellite in orbit. Thus, a Space Race of a more civilian nature was launched alongside Sputnik. The two superpowers would now compete to inspire the world with their ingenuity.

Sputnik 2 and Sputnik 3

It was important to Khrushchev that the path for manned flight was laid - and Laika the dog would seem to do just that - while the Americans had yet to successfully put a satellite into orbit.[44] Khrushchev's timeline for the second satellite demanded that Korolev produce it in time for the anniversary of the Russian Revolution in November.[45] This, along with Khrushchev's realization that the capitalist world had been quite shaken by the announcement of the successful Soviet satellite, meant the need for a repeat performance to capitalize on world reaction and international prowess escalated.[46] As a result, Laika would catch a ride to space board Sputnik 2.

Laika, a female Samoyed nicknamed "The Barker,"[47] was selected for the journey to space and provided with the necessities to support life for one week. Telemetry was provided in order to communicate important information about Laika's condition throughout the first week of orbit. Vitals such as the dog's temperature, blood pressure, and breathing rate were gathered through instruments that had been specifically made for Laika (some surgically installed) and had been part of her training for the past several months. The plan was for Laika to be fed poison or to run out of oxygen after the battery power failed, but according to Soviet records revealed years after the collapse of communism, Laika died within a few hours of being in orbit due to freezing conditions in the satellite. Some have claimed that the death happened even before that time, since torn insulation may have allowed the temperatures on board the satellite to grow higher than 100 degrees.[48]

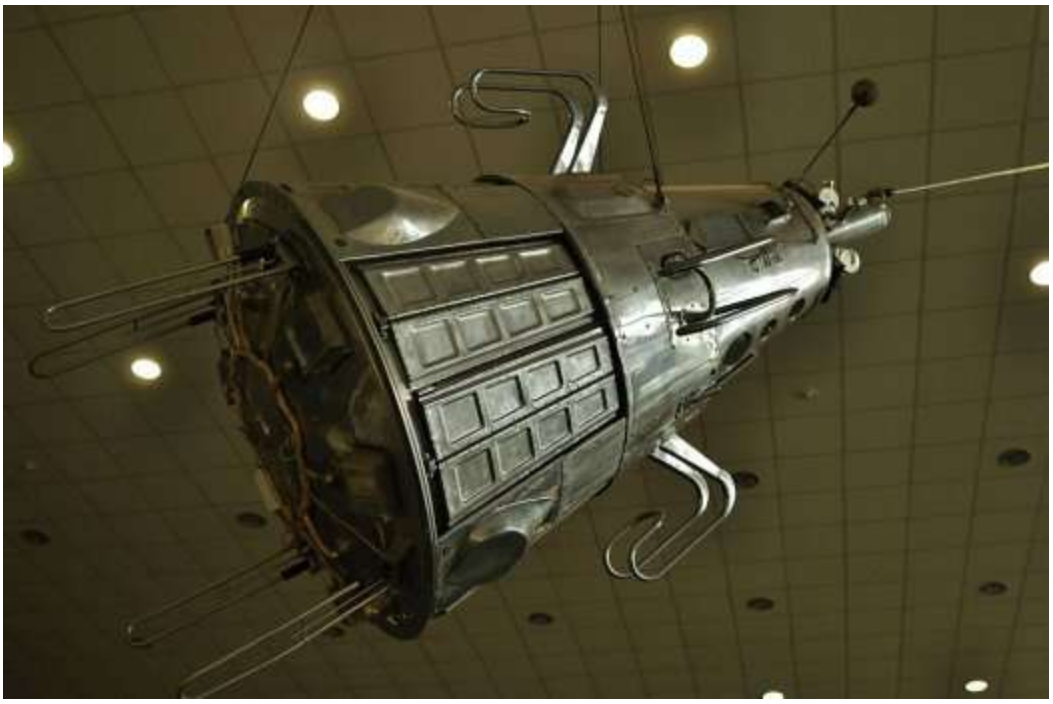
The Soviet people had a chance to hear Laika by radio when she was introduced to the public in anticipation of the launch in November.[49] Some authors have remarked on the negative response of some of the Soviet people (as well as the rarity of public criticism of government decisions) regarding Laika's journey to space and inevitable death. One of Laika's trainers, the Russian scientist Oleg Gazenko, remarked as late as 1998, "The more time passes, the more I'm sorry about it. We did not learn enough from the mission to justify the death of the dog."[50]

Laika

As for Sputnik 2 itself, the satellite was launched only three weeks after[51] the Soviet's initial victory with the satellite. Compared to the 184 pound Sputnik, Sputnik 2 weighed 1,120 pounds.[52] William Burrows notes Sputnik 2's importance in the space race, citing multiple reasons. First, the successful launch solidified the Soviet achievement for anyone who had doubted the veracity of the Sputnik launch and orbit. Sputnik 2's weight of over 1000 pounds was also confirmation of Soviet ICBM capability. Lastly, the sophistication of Sputnik 2 meant that the Russians had every intention of using their space program to gain further knowledge about the world and, eventually, to send a human to gather it.[53]

A model of Sputnik 2

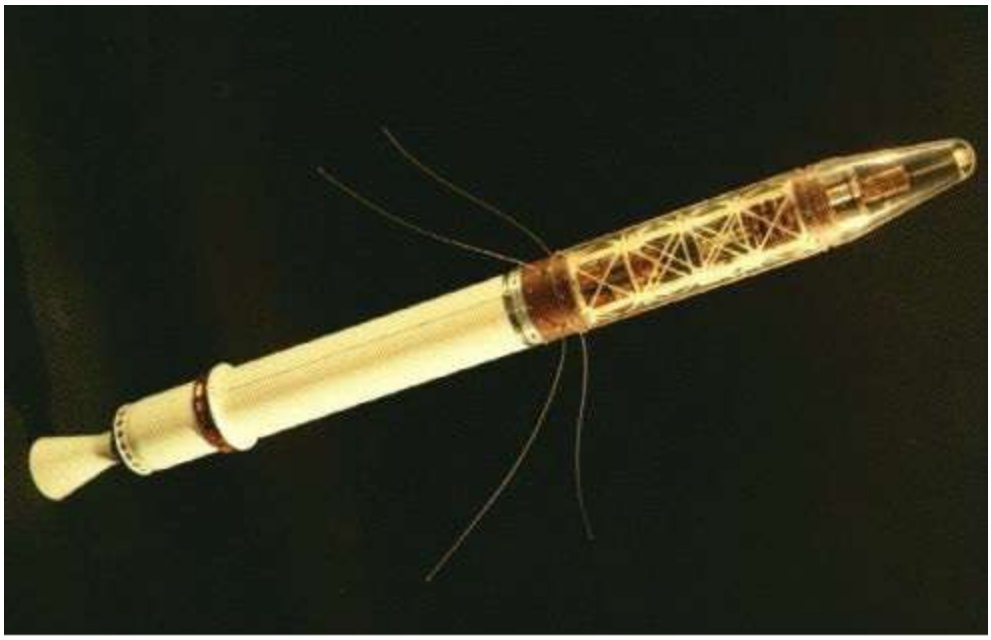
Sputnik 3 began its orbit May 15, 1958. Its main purpose was to measure, taking readings of the earth's upper atmosphere and radiation.[54] The launch of the 5000 pound satellite that was Korolev's first choice less than a year before Sputnik 1 was substituted shows the advances of both Soviet competence and confidence in a short period. Sputnik 3's launch also highlighted the sway that Korolev held over Khrushchev, whose military opposed another Sputnik launch and were openly accusing Korolev of being "too wrapped up in space."[55] Political infighting, competing loyalties, and the rivalry between the military, the Soviet space program, and those vying for power and leadership meant that several programs would compete for attention and funding. While the goal of manned space flight was clearly on the agenda, unmanned flights that would push the envelope and keep the Soviets in the record books were also worthy of attention.



Sputnik 3

The world was understandably impressed by the Soviets' successful Sputnik-1 and Sputnik-2 launches, including American scientists, naturally. Americans opened the year 1958 hoping for a fresh start in the Space Race. To get there, however, they first needed to reach the milestones set by the Soviet Union, much the same way the Soviet Union had to reach the milestones set by the Americans in the 1940s.

On January 31st, 1958, the United States proved that it, too, could launch a successful satellite into the Earth's orbit, with the launch of the Explorer I satellite. While Explorer largely mimicked Sputnik's previous successes, it did make other contributions to space science. Explorer discovered the radiation belts that circle around the Earth's atmosphere, whereas Sputnik had only revealed information about the upper layers of the Earth's atmosphere.



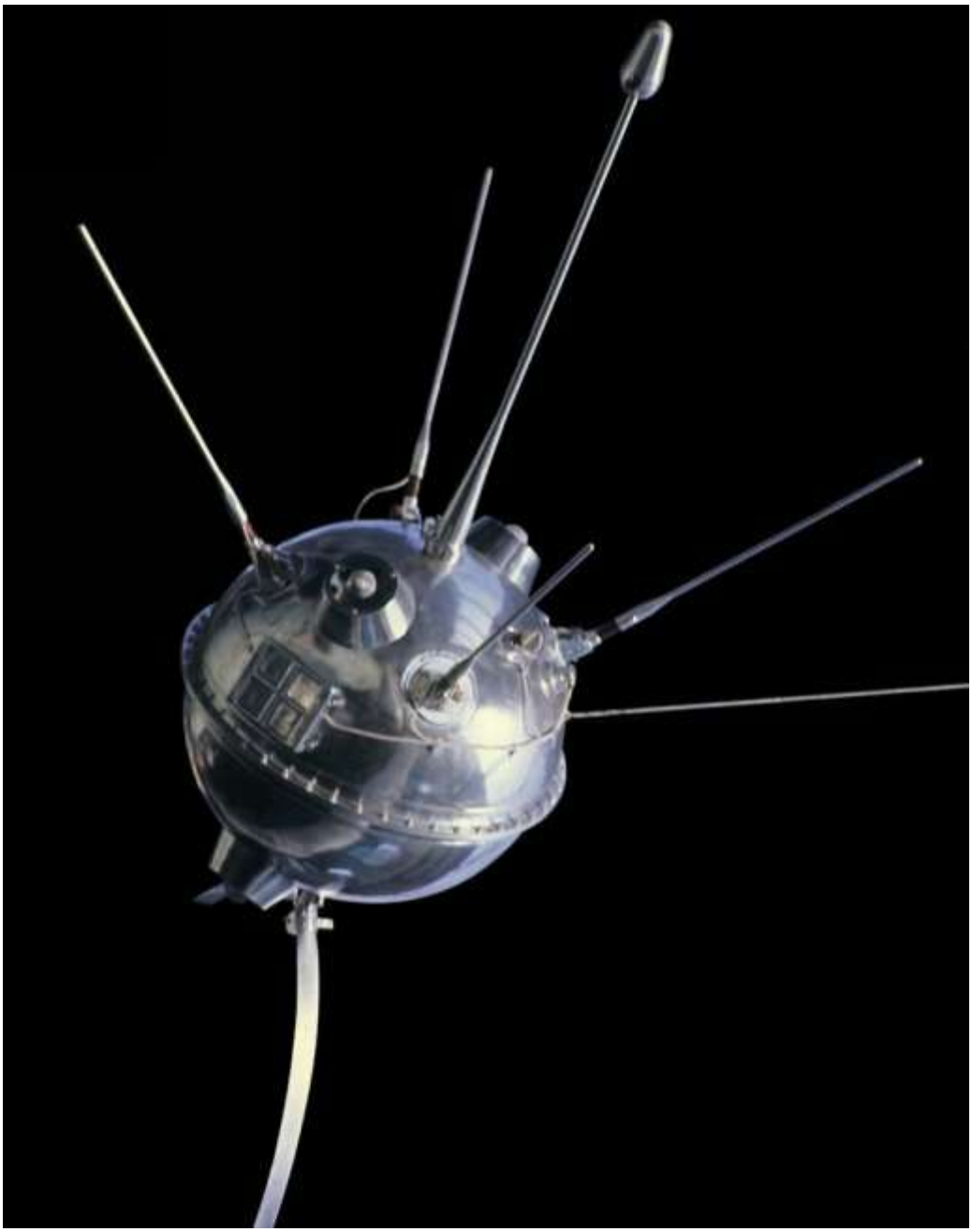
Explorer I satellite

In response to the success of Explorer I, the United States initiated the process of devoting greater national resources to space exploration. Up until 1958, all government space science was under the control of National Advisory Committee on Aeronautics (NACA). NACA, however, dated to 1915, and its original purpose focused on the realm of flight, not space. The department, however, assumed space research after World War II, but did so while also focusing on advancing flight. Its aims were expressly weapons-based; NACA was to create weapons using the science of space and flight.

With the launching of Sputnik, devoting an agency to space exploration *only* for the purpose of weapons development was outdated. President Eisenhower thought the government needed to devote resources to exploring space for its sake alone. On July 29th, 1958, he thus signed the National Aeronautics and Space Act, which authorized the creation of NASA to coordinate all space research in the United States.

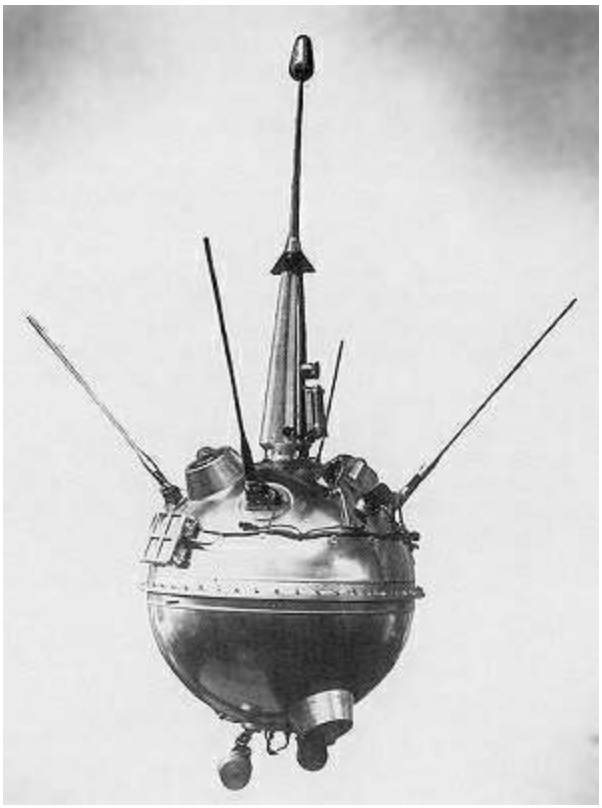
The Luna Program

Luna I was intended to be an impactor. The ball, with some significant resemblance to Sputnik, was to impact the moon and intended to give guidance to the Soviets about potential future missions there. In order to escape the orbital path it was otherwise destined for, Luna I was equipped with a rocket system designed to be put into use well into the launch. This rocket would put Luna in the path of the moon and allow the moon's gravitational pull to capture the probe. Instead, an error by ground control crews meant that Luna would miss the moon by more than 5,000 kilometers and become an orbiting "artificial planet" instead, the first craft to escape geocentric orbit. Luna I also released a bright orange colored gas that allowed scientists to track its path visually.



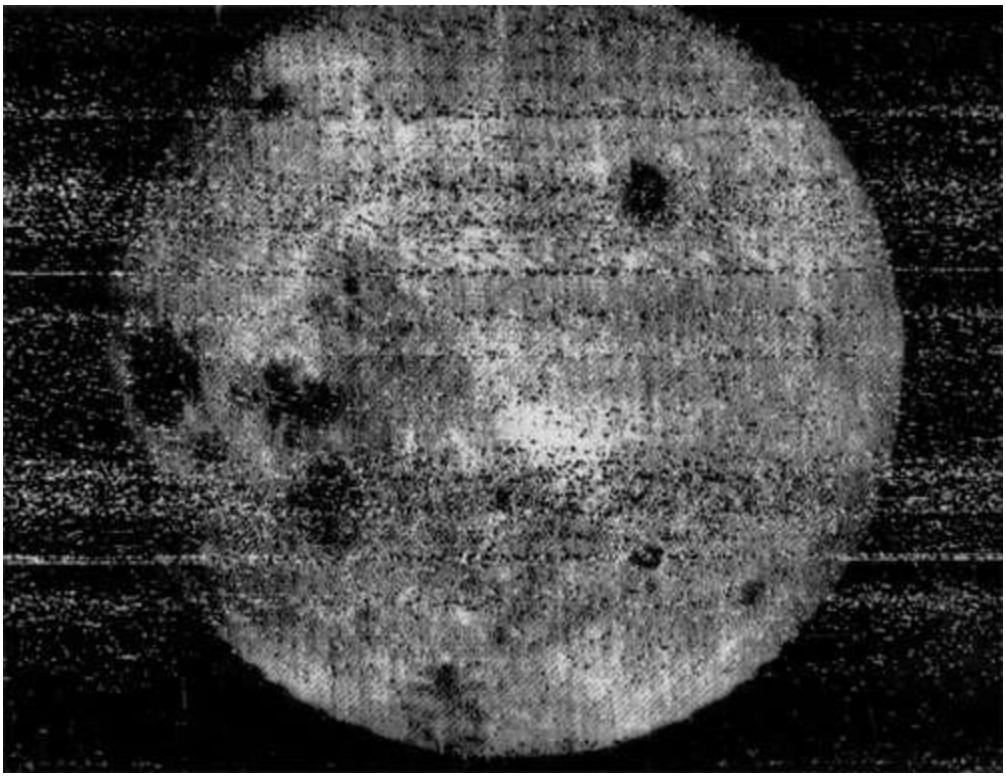
A replica of Luna I

In September of 1959, Luna 2 was launched, another attempt to reach the moon with an impactor, or a device that would hit the moon and was not intended to return or land without damage. Luna 2 hit the desired target with precision, indicating to the world not only the Soviets' ability to land a "man-made object on a heavenly body" but also a rapidly developing accuracy.[56]



Luna 2

Luna 3 made a successful journey to photograph the far side of the moon on October 4, 1959. This was another important accomplishment for the Soviets, as Luna 3 "had to fly between the Sun and the Moon, stop its rotation, point and shoot its two cameras for forty minutes while the attitude control system kept it steady and then head back to earth so the imagery could be scanned electronically and transmitted to ground stations by television as the spacecraft swung by from 25,000 miles out."[57] Luna 3's 27 photographs also "had a predictable effect upon American self-confidence, demonstrating once again that Korolev had a keen sense of how to use his rockets to dent the American ego."[58]



An image of the Moon sent back by Luna 3

With the Luna missions, the Soviets tried to further their goal of being first to the moon while avoiding the immediate cost and awaiting the technological breakthroughs required for a manned landing. Luna 9 made a successful soft landing in February of 1967, but that success followed "at least five previous attempts" by the Soviets.[59] By the time Luna 15 attempted a moon landing to pick up soil samples in July of 1969, in the midst of the American moon landing, it was official: the Soviets had lost the race to put a man on the moon. Luna 15 crashed along with the Soviet hopes to claim another space first.[60] Soviet cosmonaut Alexei Leonov described his own reaction, as well as the reaction of the Soviet scientific community, to the news that the Americans had landed on the moon: "If it couldn't be me, let it be this crew, I thought, with what we in Russia call 'white envy' envy mixed with admiration…Even in the military center where I stood, where military men were observing the achievements of our rival superpower, there was loud applause."[61]

Leonov (left)

Luna missions also had the goal of reaching Mars and Venus first, but there were several failures along the way (in fact an over 50% failure rate, though lower than the American rate).[62] William Burrows suggests a link between manned and unmanned Luna missions in that successful unmanned missions were always indications to the Americans that a manned flight with similar goals was soon to follow.[63] Soviet cosmonauts of the future would become

more and more frustrated with automata, believing that the human role was being replaced by less expensive and less risky unmanned exploration.

The Luna missions continued, in competition with other Soviet efforts (including manned missions), throughout the 1960s and ‘70s. Though the Soviets had later success, such as Luna 16 and 17’s soft landings and data and photography collection, “they would in effect amount to toys that crawled in the shadow of the astronauts.”[64]

The last of the Luna missions took place in 1976 when Luna 24 made a successful soft landing on the moon and collected a soil sample after drilling approximately two meters into the moon’s surface. At the time, the Russian claim to have found water on the moon was ignored by many Western scientists who believed that the soil samples collected by the Apollo missions had proven that there was no water on the moon. Later astrophysicists, such as Arlin Crotts, now credit the Soviet Luna 24 mission as properly gathering a sample with reliable measurements.[65]

The First Manned Space Missions

Three years after Sputnik 2 had taken Laika into orbit, the Soviets were ready again to use canines in space, and this time with a provision for the animals to return safely to earth. Obviously, the recovery of an animal after space flight was an important hurdle that had to be cleared before a manned flight could be considered. Thus, two dogs selected from the space program's trained canine group were to take part in the first Vostok mission: Belka and Strelka.[66] Like Laika, the new canine cosmonauts would be launched from the Baikonur facility.

Burgess and Dubbs outline several concerns regarding the Vostok program. First was the concern that an adequate heat shield could be developed to protect life upon re-entry into the earth's atmosphere. Second, it was important to determine whether sufficient systems for supporting life could be put in place. Lastly, the Soviets wanted to see if the effects on the space traveler, whether human or canine could be measured, predicted, and dealt with. Naturally, the Soviets, criticized both at home and abroad for the death of Laika in Sputnik 2, also wanted to ensure the safe return of Belka and Strelka for moral reasons as well.[67]

Despite problems that were not anticipated during flight, Belka and Strelka returned to Earth after 25 hours and made it through re-entry alive and well. In the aftermath, Belka and Strelka became Soviet celebrities, pictured on advertisements, postcards, and sought out for photo-ops with Soviet politicians.[68] One of Strelka's puppies was later given as a gift to Jacqueline Kennedy, though Burgess and Dubbs report that the dog had to undergo multiple tests to ensure it was not outfitted with any type of spying device.[69]

The two space dogs

Training for Soviet cosmonauts who would soon enter space for the first time took place in Star City, a highly secret training ground in Kazakhstan. The Cosmonaut Training Center's construction was ordered by the Soviet Ministry of Defense in January of 1960.[70] Baikonur's location in Kazakhstan was not only a practical choice but a philosophical one that emerged from the Soviet attitude toward its space program and its designers and cosmonauts, according to the authors of *Epic Rivalry: The Inside Story of the Soviet and American Space Race*. The Soviets, in contrast to the Americans, built "a sealed-off world, always detached and inaccessible, a military precinct carefully hidden from public scrutiny."[71] The Kazakh location provided practical advantages as well: enough room for easy recovery of re-entry vehicles, the space needed for the number of launch pads, dual radio stations, and other ground support for launches, and the location nearer to the earth's equator.[72]

A look at the website of Gagarin Cosmonaut Training Center at Star City, as it is known today, is a reminder of the earliest decisions in Russian space history. Korolev is quoted as recommending air force pilots as future cosmonauts: [Air force pilots] "are trained better than anyone else, especially fighter pilots. A jet fighter pilot is a required universal person. He flies a single-seat, high-speed jet in the stratosphere. He is a pilot, an air navigator,

an operator and a flight engineer at the same time..."[73]

Despite the fact that the Soviet cosmonauts, as well as others from around the world in later years, have trained at Star City for over 50 years, much about the place has remained secret. The only published and dedicated work on Star City to date is by a Dutch author and researcher, Bert Vis, who was allowed multiple visits after 1991.[74]

The Soviet training dynamic made Star City unique from the beginning. It was decided that the style would be like that of a campus, an isolated place where cosmonauts would not only train, but live. A wooded area 25 miles north of the nearest city was selected, one that allowed it to remain relatively hidden away but to maintain access to the Soviet air base nearby.[75] Vis's book contrasts the American approach to training flight crews to the Soviet approach. While the Americans trained a crew for each mission, as well as potential individuals to serve as replacements if necessary, crews at Star City were trained as wholes, usually in groups of two or three. If a flight crew member needed to be replaced, it was likely that the other members of the crew would be replaced as well.[76] Final selections for a flight were made known very close to the actual launch of the mission and kept secret, even from family members. For example, Yuri Gagarin's relatives only found out about his successful launch from news announcements.

Though eventually Star City would grow large enough to encompass almost all areas of training, it at first served an administrative role and as the center of physical training for the cosmonauts. Technological training for missions, as well as simulation took place elsewhere, partly because of the limited facility (at its opening, Star City had only one two-story building) and partly because of infighting between those who built the spacecrafts and the trainers of the cosmonauts themselves.[77]

In time, the facility would grow to include multiple buildings, a gymnasium, dormitories, flight simulators, and a pool over the next 5-7 years, but funds and permissions were sometimes hard to come by and definitely unpredictable. The Soviet government allocated funds as they saw fit, at times heeding the call of the directors of Star City, and at times ignoring them. While the facility might have money dedicated to major projects, it seems at times the most practical needs went unmet. Vis relates a story from

the diary of Kamamin, Star City's early director, about attempts to obtain transportation for cosmonauts to facilities in Crimea and Baikonur. Despite some state-of-the-art technology, the provisions for living conditions and the convenience of the cosmonauts were not foremost concerns, it seems. Kamamin complains that his cosmonauts were, at times, reduced to hitchhiking in order to get to the training facilities for water recovery or mission control, creating potential safety issues.

Despite the difficulties faced by the Russian cosmonauts, the Soviets would beat their rival to the next space feat: manned space flight. This can be credited to the way the Soviet program developed, with concentration on ballistic missiles, then sounding rockets (designed to gather information from the upper atmosphere or just into space) and finally to spacecraft that could be launched by carrier vehicles.[78]

Yuri Gagarin entered Vostock I on April 12, 1961, chosen out of 20 cosmonauts in his training program at Baikonur for the first manned space mission. Gagarin was unknown to the outside world, though his name and desire for information about his background would increase greatly upon his return from space. As Hall, David, and Vis explain in *Russia's Cosmonauts*, the Russian tradition of cosmonaut training focuses on anonymity until a mission has been launched. This way, for those who trained as cosmonauts but were never selected for space flight, their names remain unknown to the rest of the world and the Russian scientific community.[79]

Rodgers speculates that Khrushchev made the final decision for Gagarin because of their similar peasant backgrounds, though his main competitor, Gherman Titov, was later to say that the right choice had been made since Gagarin was a better public relations choice.[80] Indeed, authors Jamie Doran and Piers Bizony argue that Gagarin is the only example of a Soviet hero, since "to be a hero under communism is an anomaly, for no individual could be greater than the collective whole."[81]

Gagarin in the space capsule

Though it is easy to see (and common for Americans to believe) that early space cosmonauts or astronauts were pioneers deserving of recognition and respect, when one realizes the level of unknown that these men and women faced, their status as heroes becomes even more clear. When Gagarin took flight in Vostok I, he had only experienced weightlessness for 2 to 3 seconds, courtesy of a free-falling elevator in a tall building in Moscow. The elevator car's descent would be stopped by blowers at the bottom of the 28 story shaft, allowing cosmonauts to experience only a glimpse of a world without gravity.[82] In fact, Doran and Bizony state that the Soviets had no particular confidence that a man could survive a 24-hour period without gravity, so new was the concept. The American space program used stripped cargo planes flown in "parabolic arcs" that would allow up to two minutes of gravity-free flight for astronauts in training.[83]

No matter what kind of preparations were taken, space flight was unpredictable, and the risks were many. Additionally, one of the largest areas of concern for the Soviets was the public relations coup, and not primarily safety of the cosmonauts. The space program and government prepared three envelopes to be released to the press after the launch of Vostok I: one in case of complete success, in which Gagarin's victory would be broadcast to the world; one in case the capsule or the parachuting Gagarin descended onto foreign territory; and one in case of disaster, such as an explosion or the

capsule being lost in space and unable to return to Earth, dooming Gagarin to death from thirst, starvation, or lack of oxygen, whichever came first.[84]

A model of Vostok 1

Vostok 1 weighed over 5 tons, and the spacecraft itself was called Swallow. Before the launch, Gagarin was assisted into his orange cosmonaut suit and approached the elevator before speaking to those who were invited to the observation: “At this instant, the whole of my life seems to be condensed into one wonderful moment. Everything that I have experienced, everything that I have done hitherto, was experienced and done for the sake of this moment...Of course, I’m happy. In all times and epochs the greatest happiness for man has been to take part in new discoveries. To be first to enter the cosmos, to engage, single-handed, in an unprecedented duel with nature….could one dream of anything more!”[85]

Gagarin left earth at 9:07 a.m. Moscow time,[86] and during his 89 minute orbit, he experienced weightlessness: “Up and down no longer existed. He was suspended in physical limbo, kept from floating about loosely only by

the harness strapping him to his contoured couch. About him the magic of weightlessness appeared in the form of papers, a pencil, his notebook, and other objects drifting, responding to the gentle tugs of air from his life-support system fans."[87]

The flight lasted just a few hours, with Gagarin returning to Earth by braking at the edge of the atmosphere, ejecting from the capsule at a planned point, and then parachuting to the ground. The actions of ejection and parachuting came close to costing the Russians their place in history, as one of the rules in place for space flight records required that the vessel that was launched returned to Earth still manned. In the case of both Vostok 1 and 2, the cosmonauts ejected, as planned, from the capsule.

Announcements issued from the Soviet government were hazy about the connection between cosmonaut and vessel, committing only to reports that both cosmonaut and vehicle touched down "somewhere near" a designated field. This controversy was settled later when it was determined that the manned orbit of space, and not the landing, was what mattered for scientific records.

After the Soviets beat the United States to the first successful manned space mission, *Life Magazine* featured Yuri Gagarin greeting Khrushchev on its April 1961 cover, with the accompanying article's introduction including these lines of admission: "For men everywhere, this astounding exploit should have been a matter of pure exaltation. It was a victory for a long scientific effort in rocketry everywhere and the result of extraordinary preparations in Russia. The mysteries of outer space for the first time seemed to lie within the measure of human instruments. But even as Earth's gravity reasserted its pull upon the returning capsule, the agonizing ears and suspicions of the cold war moved in to tarnish Gagarin's courageous act. Nikita Khrushchev openly brandished at the West his new sign of Soviet power."[88]

The same article featured quotes from a section entitled "Some Reactions Overseas", a follow-up to its words on the reactions from Washington, from Kennedy to key senators and frustrated NASA scientists quoted anonymously. The quotes featured seem to promote the narrative of U.S. humiliation in front of a watching world: A German secretary realizes

"Soviet boasts of ultimate superiority may not be groundless after all," while an African student in Paris remarks, "The Americans talked a lot. Russia kept silent until success came. The results speak for themselves."[89] It seemed in the immediate wake of Soviet news that any U.S. answers would be inadequate. Referencing the promised Mercury launch, *Life* declared, "Now, even if everything goes off on schedule and an Astronaut is launched late this month or early next, the achievement will seem pallid."[90]

While that didn't end up being true, the name Yuri Gagarin has become inseparable from Russian space history. A popular story recalls Gagarin's return to Earth from his trip in space in 1961. As two women, a mother and daughter, worked in a potato field, they were approached by a man in an orange space suit and white helmet.[91] He acknowledged that he had indeed come from space. As Paul Rodgers writes in *The Independent*, the legend of "a Soviet hero being welcomed home by his fellow peasants, a wise mother and a child of the future"[92] fit the government's purposes perfectly, but was also likely "true in essence." Calling him "a poster boy for the Soviet space programme,"[93] Rodgers goes on to recount Gagarin's youth, growing up under collectivization and eventually being sent to technical school, where he experienced his first flight.

Gagarin, standing at only 5'2" (which was considered a positive in the days of early space flight), married only a few weeks after the launch of Sputnik and eventually was invited to take part in the cosmonaut training programs that resulted from the excitement for manned space travel.[94] *Life Magazine* reported that he had only recently become a member of the Communist Party (unlike the soon-to-be renowned Valentina Tereshkova), though he was quickly proclaimed a Soviet Hero, given military honors, and celebrated his triumph in Red Square at Lenin's sacred grave[95] saying to the crowds, "One can say with assurance that in Soviet spacecraft we will fly even over more distant routes. I am boundlessly happy that my beloved homeland was the first to accomplish this flight, was the first to reach outer space."[96]

As fate would have it, Gagarin never made another space flight, which would prove especially important in light of the controversy over Soyuz I, a capsule that some see as having been doomed to failure and one that Gagarin was supposed to man. Gagarin never repeated his space mission, but he

remained involved with the program until his premature death in 1968 as a result of a crash of his MiG-15 test plane.

Many years of controversy and conspiracy have followed Gagarin's death, but a 2010 article in *The Telegraph* reported the claims of a Soviet investigator who had been studying Gagarin's crash for over seven years. The findings of the Russian study indicated that Gagarin's sudden and dramatic descent into a forest was likely a result of an overreaction - pilot error on the part of Gagarin when he realized that a vent on the MiG-15 had been left open. As the plane descended at rapid speed, it is now the conclusion of Russian investigative teams that Gagarin and his trainer blacked out and were unconscious at the time of the crash.[97] Gagarin's ashes were buried in the wall of the Kremlin, giving him a place of continued honor amongst other Soviet heroes.[98]

Regardless of what American leaders privately believed, a national debate ensued over the importance of the American space program, marking a significant transition in thinking. Although the Americans were unable to one-up Soviet space achievements, they proved quite adept at mimicking them. Just as the Americans followed the Soviet Sputnik with the American Explorer, they offered Alan Shepard Jr. as their own version of Yuri Gagarin.

While the Soviets were the first to put a man into space, the Americans weren't entirely lost in the effort. NASA had been making preparations for a manned mission to space for years, though they failed to materialize before the Soviet mission in 1961. Much like the Explorer mission, however, the Americans were able to put a man into space within just weeks of Yuri Gagarin's journey.

On May 5th, 1961, Alan Shepard became the second person and the first American to venture outside of the Earth's atmosphere, doing so aboard the Freedom 7 mission. Compared to Gagarin's mission, however, the Freedom 7 was unimpressive. Unlike Vostok, Freedom 7 did not ever orbit the earth. Instead, it was a suborbital mission that moved along a strictly ballistic trajectory. It launched on an arc, reaching outside the Earth's atmosphere before quickly descending back down to the planet. Shepard entered outer space, but he did little else. The mission was more akin to the planning stages of the Soviet Vostok mission.

Shepard in flight

Regardless, the political statement was sufficient enough. Freedom 7 proved that the U.S. had the rudimentary technology to launch a man into space, though it also made clear the U.S. was technologically behind the Soviet Union. On the home front, though, Americans were pleased with the mission, happy that it had not resulted in total failure.

Today the most memorable part of the Space Race was the successful Apollo 11 mission, which fulfilled President Kennedy's ambitious goal set years earlier. But Apollo 11 was only one of nearly 20 Apollo missions conducted by NASA, and the program was started by the Eisenhower Administration right at the beginning of the decade. Apollo 11's success would only come about after nearly a decade of technological advances, hard work by NASA scientists, intense training by astronauts, and several missions preceding Apollo 11. The program also cost over $20 billion, making it the most expensive peacetime program in American history up to that time.

Prior to the 1960s, no declared race to meet certain achievements in space actually existed. Instead, the Soviets and the Americans competed only tacitly. American defeats could, therefore, be downplayed through denial. American Presidents congratulated the Soviets on their achievements,

publicly acting as though the Soviets' feats in space were beneficial to mankind, not the result of a competition.

No one really bought that spin, and it was completely gone with Kennedy's speech, which came just months into his presidency. When Kennedy announced his support for a manned mission to the moon to a joint session of Congress, he did not only give his seal of approval; he committed the United States to landing a man on the Moon before the close of the decade. Never before had space-related achievements been pinned to a publicly-defined goal, and it would fall upon the Apollo program to make the goal a reality.

With that very public statement of the country's goals, the Soviet Union and the United States began an open and candid race to land a man on the Moon. Of course, that goal was also set at a time when the two sides had reached their technological limits just sending a person into Earth's orbit and sending a satellite into the Moon's orbit. There was still the matter of safely landing a spacecraft on the Moon's surface, launching it back to Earth, and safely landing it back on the Earth's surface.

While work began in earnest toward making manned missions to the Moon, there was still the matter of successfully putting an American in orbit around the Earth. That came on February 20, 1962, with John Glenn orbiting the Earth nearly a year after Gagarin's orbit.

Glenn

Meanwhile, subsequent Vostok missions followed closely on top of one another, largely for political reasons. Khrushchev desired an atmosphere of continual Soviet success and one that would put continual pressure on the Americans, as well as encourage the satellite countries to stay in line. Soviet scientists and engineers were by now used to launch times and priorities being set by anniversaries and the suspected progress of the U.S., not by particular readiness. Part of the timing for the landing of Vostok 2 was designed with the construction of the Berlin Wall in mind, a show of irresistible Soviet power and strength. Though the next two Vostok missions were similar in scope and length (a four day and three day mission), they gave off the deliberate illusion that the Soviets were accomplishing a "space rendezvous," an event in which two manned space flights made contact with one another. This was an exaggeration at best, but one the Soviets allowed to be assumed by observers who noted the parallel times of the flights: "With all the secrecy we had in those days, we didn't tell the whole truth…as they say,

a sleight of hand isn't exactly a fraud. It was more like our competitors [in the east] deceived themselves all on their own. Of course, we didn't want to shatter their illusions."[99]

Cosmonaut Gherman Titov, who had been the backup cosmonaut for Vostok 1, was in orbit for 25 hours at only 25 years of age, making him the youngest person in space to this day.[100] Though his mission was later overshadowed by the many Vostoks and other missions to come, Titov understood the importance of flights that were not necessarily firsts but simply furthered the overall goal of space flight: "Now we must accumulate experience in construction of space technology, elaborate the methodology of training man to live on board spacecraft. I won't conceal that the Soviet space programme envisaged follow-up space flights. The Vostok 2 was ready to go. We awaited the opinions of medical specialists and biologists who analyzed the results of the first manned flight. We wanted to know, in particular, what impact space factors had on man's organism. Opinions on this differed. By no means everyone agreed, and certainly not at once, to the proposal of a 24 hour flight. It was suggested that we should limit ourselves to three or four, a maximum of six orbits. But why should we mark time?"[101]

Titov

Titov, indeed, suffered from some space sickness during the flight, but he managed to carry out the experiments and communication as planned. He also slept in space, commenting, “I slept the sleep of the just and spent 35 minutes longer than envisaged by the programme. My sleep was good, without dreams. In contrast to earth conditions, I didn’t feel the necessity of turning side to side.”[102] However, Titov struggled with some aspects of recovery, particularly balance issues, causing some concern about man’s

ability to adjust to longer periods without gravity. Bond speculates that this "may be why there were no more manned space flights for a year."[103]

Vostok 3 and 4 added to the manned Soviet space flight time, but they also had the distinction of being in orbit at the same time. Though the original intent had been for the flights to "rendezvous" to a limited extent, the orbital patterns were a bit off and they never came closer than 5 kilometers. It is important to note the accomplishments of the two missions, however, which not only continued to shock the world but also "demonstrate the Soviet capability to track an orbiting spacecraft accurately, to launch a craft into a pre-determined orbit accurately, and to control simultaneously two craft in orbit."[104]

Vostok 5 was launched June 14, 1963 with cosmonaut Valery Bykovsky aboard, answering to the call-sign Hawk,[105] and Vostok 6 was the latest Soviet accomplishment that appeared (on the surface, at least) to prove that the Soviets were ahead in the race to space milestones. Bykovsky orbited the planet for over 119 hours and safely returned to Earth in the same manner as previous Vostok missions by ejecting and parachuting to earth after re-entry. The Americans, in contrast, had just completed their longest manned-vehicle orbit with the Mercury mission in May of 1963, lasting only 34 hours.[106]

Bykovsky (left)

Though Bykovsky's mission had set a new record for manned space flight, only two days into his mission, a new groundbreaking development was waiting on the launch pad in Baikonur. Valentina Tereshkova, the first woman in space, entered orbit, along with Bykovsky, on June 16, 1963 on Vostok 6. She had been selected from a team of five female cosmonauts chosen for training. Those not selected included a mathematician and programmer, an engineer, a teacher, and a stenographer and secretary.[107] Valentina Tereshkova, a weaver[108] who had also qualified as a parachuting champion, was "ideal for Khrushchev's purposes: fit, handsome, sufficiently smart for the intellectual challenges of space training, but not so advanced in her education that she could not safely represent the ordinary peasant and working classes."[109]

Tereshkova

Doran and Bizony again note that much of Soviet decision-making and response in space fight was inexorably tied to politics and public relations. Khrushchev, they explain, needed a quick and noticeable victory in the days following the Cuban Missile Crisis. It was this, they claim, that brought about his desire to "launch the kind of person no one had thought of before, a woman." Others credit the idea for the first woman in space to Korolev, who was looking for "a new first"[110] and desired to send the "message that the

Soviet Union valued its citizens equally and give little girls throughout the nation the belief that they, too, could go into space someday."[111] This idea is in contrast to other historians who claimed that Korolev and other Soviets were angry that a woman had been chosen, were skeptical of her abilities, and that Korolev vowed he would not work with a female cosmonaut again after Tereshkova's difficult mission.

Tereshkova orbited earth for almost 71 hours, besting the total time of all American manned flights combined, and from space, she spoke on Moscow Radio: "Here is Seagull. I see a yellow strip. I see the earth. Everything is in order. I'm feeling fine. The machine is working well."[112] Tereshkova's flight later came under criticism for not accomplishing all of the mission goals in the areas of data collection and manual control of the craft. Some engineers reported later that Tereshkova had become ill as a result of not being able to handle the weightlessness during flight and grew more and more unable to provide ground control with the data needed.[113] Tereshkova herself disputed these claims and said she "felt no fear."[114]

Though a plan was in place for future Soviet female cosmonauts, the next Russian female did not enter space for 18 more years. Vladimir Putin extended an invitation in 2013 to Tereshkova on her 70th birthday, telling her, "Your flight was, and will remain, a matter of pride for the Soviet people, for the Russian people."[115] That same year, she offered herself for a manned mission to Mars,[116] stating, "If I had money, I would enjoy flying to Mars. This was the dream of the first cosmonauts. I wish I could realize it! I am ready to fly without coming back."[117]

The Vostok missions had clearly set the Soviet Union apart, excited its leaders and people, and upset the Americans, who still seemed to lag behind in their efforts. It is the opinion of many, however, that while the Vostoks were efforts that broke records, they were also less well-planned, being driven in many cases by Khrushchev's desire to grab headlines rather than actually moving a viable space program forward. As Peter Bond comments, "The Soviet leadership had stung the pride of the richest and most technologically advanced nation on the world, and had started a race which they could not win, at least in the short term."[118]

Mars Missions

In April 1961, Gagarin's flight captured all the headlines, and Kennedy's call for sending men to the Moon gained the world's notice a month later. But the Soviets had already looked far beyond the Moon half a year earlier, when it attempted to launch probes to Mars in October 1960. Those first two probes were intended merely to fly by Mars and transmit photos of the planet. In addition to getting closer looks at the Red Planet than ever before, the true value of those 1960 missions was the propaganda victory the Soviets hoped to score, obtaining yet another notch in their Space Race belt. But it was not to be. Both probes failed to leave Earth's orbit before crashing. Though the Soviets' missions failed that year, they were still years ahead of the United States, which was already making manned missions to Earth's orbit and the Moon focal points of their space program and would not attempt a mission to Mars for nearly a decade.

Given the fact that the Space Race's competing missions to Mars took place in the aftermath of the Apollo program's Moon landings, they are often viewed as more of an afterthought than a main event. But the race to Mars was just as tightly contested as any. In November 1971, NASA's Mariner 9 became the first spacecraft to enter Mars' orbit, but the Soviets' Mars 2 and Mars 3 spacecrafts were hot on its heels, and those two spacecrafts had far more ambitious plans. Whereas Mariner 9 intended solely to orbit Mars, Mars 2 and 3 had descent modules that were meant to land them on the Red Planet's surface itself. The descent module aboard Mars 2 crash-landed on the surface on November 27, but less than a week later, Mars 3's descent module began an historic descent down to the surface. On December 2, 1971, after a few hours of descending, it successfully completed its "soft landing."

Mars 3 was poised to become the first functional probe on Mars' surface, but it ceased communicating entirely within just seconds of landing on Mars. To this day, it's unclear why Mars 3 suddenly failed, and the answer might not come until a rover reaches its location (or a human does). The likeliest explanation is that Mars 3 landed in a dust storm that quickly knocked it over. Whatever frustration the Soviets experienced with Mars 2 and Mars 3 was only made worse with Mars 6 and Mars 7, which were launched within days of each other and reached Mars in March 1974. Mars 6 malfunctioned during

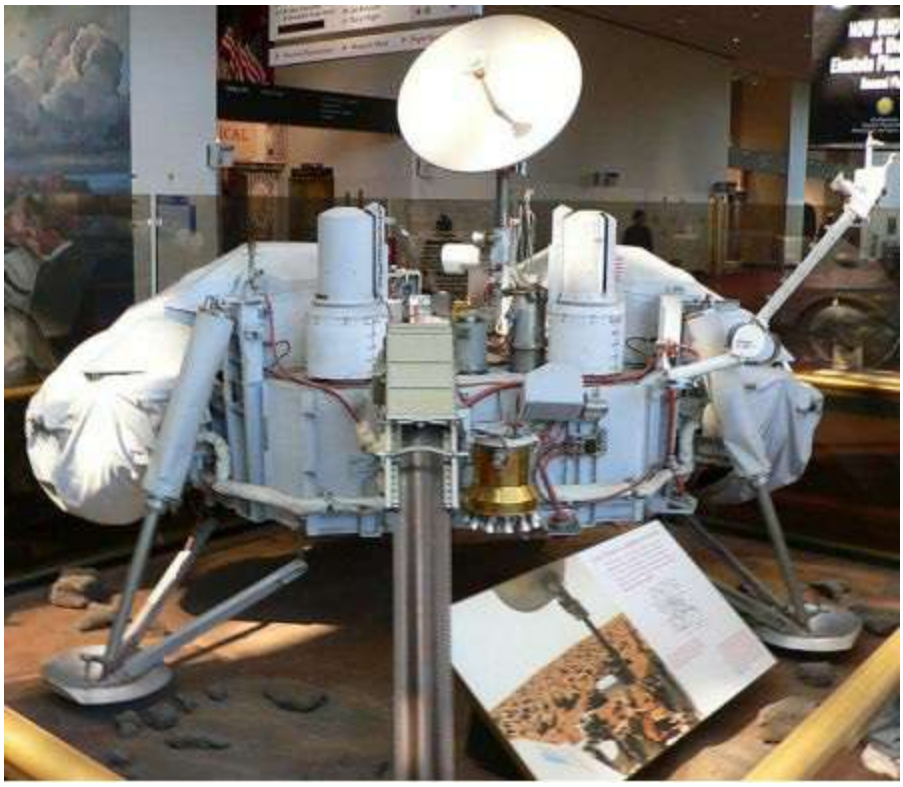
descent, while Mars 7 malfunctioned before descent and is possibly still orbiting around the Sun today. As a result, the Soviets never successfully landed an object on Mars that transmitted data, and the "Mars Curse" continues for the Russians to this day. After the Soviet Union collapsed, the Russians' Mars mission suffered a failure during launch in 1996, and another mission suffered engine failure in 2011. The Russians plan to try again in 2012.

Replica of the Mars 3 Lander

Mars 3's failure left it to NASA's Viking program to make the first successful transmissions from Mars' surface. Mariner 9 spent hundreds of days orbiting around Mars, taking pictures and mapping the Red Planet's surface, which allowed NASA to come up with potential landing sites for the upcoming Viking missions. Several years before Mariner 9, NASA had begun designing missions for unmanned landings on Mars that would use a spacecraft consisting of an orbiter module and a landing module. The design of the modular spacecraft came from NASA's successful use of a similar spacecraft delivery system for the Apollo program's manned missions to the Moon. The landers had smaller engines to help it properly descend to the surface, as well as a set of legs that would allow it to stand upright on the

surface. Equipped with antennae and a transmitter, the landers could communicate with the Earth

On August 20, 1975, Viking 1 was launched to Mars. 20 days later, Viking 2 was on its way too. Both Viking landers were huge successes just for landing on Mars and transmitting data, but they would end up succeeding far better than NASA ever intended. NASA hoped the Viking missions would provide better images of Mars' surface and the ability to determine the chemistry and biology of the soil, which everyone hoped (and still do) might indicate signs of life. The Viking orbiters continued orbiting around Mars for a few years, taking thousands of pictures and even thermally mapping the heat on mars' surface. The Vikings' pictures showed deep valleys on Mars' surface, clear evidence that liquid, potentially water, was once abundant on the surface. The Viking landers were even more successful. Both Viking landers functioned on Mars' surface for several years, successfully analyzing the soil, weather, and atmosphere while providing pictures from the surface. After nearly four years, Viking 2's battery failed, but Viking 1's lander continued transmitting data. In fact, Viking 1's lander only stopped functioning after a human error at NASA inadvertently shut down the lander's antenna, over six years after it had landed on Mars.



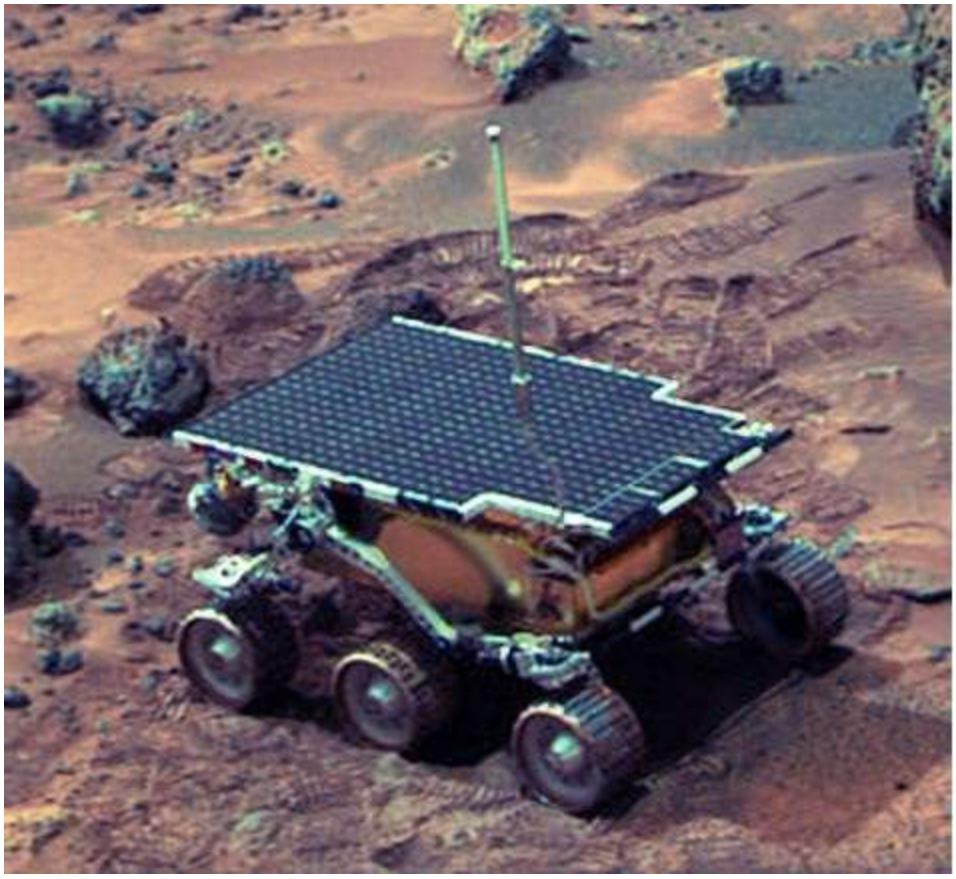
Model of the Viking Landers

Viking Orbiter

Picture of Mars' Surface from Viking 1

The Space Race's initial forays to Mars laid the groundwork for the ongoing exploration of the Red Planet, which continues to be explored by American rovers on Mars' surface. The world knew of the Soviet Union's famous Mars 2 and Mars 3 missions, particularly the former's crash landing and the latter's mysterious malfunction shortly after landing. But a top secret aspect of those missions that stayed secret for nearly 20 years was that the landing modules were carrying small rovers, which the Soviets intended to use for conducting soil readings. About 25 centimeters long and weighing less than 10 pounds, the rovers were designed to move around on skids attached to the landers at about a mile per hour. On July 4, 1997, over 25 years after the Soviets tried to use a rover on Mars, NASA's Sojourner rover wheeled down a ramp out of the Mars Pathfinder and became the first

operational rover on the Red Planet’s surface. At two feet long and weighing about 25 pounds, Sojourner resembled a miniature ATV with six-wheels.



The Sojourner on Mars

The Voskhod Missions

In 1964, the Soviets began the Voskhod missions, apparently at the behest of Khrushchev, who was said to be impatient for another successful and headline-grabbing mission before the Americans could have success with a two-man crew.[119] Voskhod was to carry three men, including a doctor and a scientist rather than traditionally trained cosmonauts, but the increased weight of the new craft and its passengers would require that some of the safety measures from the Vostok designs would be removed, making Voskhod 1 "possibly the most dangerous mission ever."[120] As Korolev modified the Vostok capsule to fit three men instead of one, several traditional safety precautions had to go. According to Korolev's deputy, Vasily Mishin, "Fitting a crew of three people, and in spacesuits, in the cabin of the Voskhod was impossible. So- down with the spacesuits! And the cosmonauts went up without them. It was also impossible to make three hatches for evacuation. So- down with the ejection devices."[121]

Voskhod 1's crew

The Voskhod's main differentiation from earlier flights was the landing procedure. Voskhod would bring its crew to the earth, with no more ejection seats or parachutes necessary. As Korolev put it, "Soviet designers have taken care to minimize loads on the human organism and the landing system ensures that when the craft touches Earth, its speed is down to zero and it lands softly."[122] Another major difference was in what the crew wore - "sky blue jackets over lightweight, dark gray suits and white helmets," rather than pressure suits.[123]

Mishin questioned the validity of Voskhod from a scientific perspective: “It was as if there was, sort of, a three-seater craft, and at the same time there wasn’t. In fact, it was a circus act, for three people couldn’t do any useful work in space. They were cramped just sitting! Not to mention it was dangerous to fly.”[124]

While Voskhod I was in flight, there were significant developments taking place on the ground. Khrushchev was ousted from leadership, a development that later gave significance to his comment during a conversation with the Voskhod cosmonauts that a member of the Politburo was “pulling the receiver out of my hand.”[125] Perhaps as a result of the political turmoil, Voskhod 1 landed, the first successful manned space landing, only about 24 hours after launch. When the crew landed, Leonid Brezhnev was the USSR’s new leader.[126]

Brezhnev

With Khrushchev’s ouster, the Soviet space program lost some of its vigor

and its sense of urgency diminished. Though some may argue that Khrushchev's reasons for supporting the space program were solely political and served to distract the people from his failures in agricultural and foreign policy, there can be no doubt that he "turned the USSR into an unlikely beacon of technological progress."[127] Brezhnev simply did not place as much emphasis on Soviet space feats. As Brzezinski explained, "Moscow still aimed for the moon, the ultimate bragging ground, but the effort did not have the same intensity or urgency as the past-Sputnik rush to paint the heavens red…With the milestones in space growing ever more ambitious and costly, the Kremlin's cautious new bosses preferred to spend on security rather than prestige."[128]

As a result of their frustrations with the lack of funding for manned space flights during the Brezhnev years, several cosmonauts signed a letter directed to the premier:

> "Dear Leonid IIyich!
>
> We are writing to you to raise certain issues, which we consider very important for our state and for us. [After a brief review of Soviet space and cosmonaut history and its importance for Soviet prestige, the letter continued] …In the past year…The USA have not only caught up with us, but even surpassed us in certain areas… This lagging behind of our homeland in space exploration is especially objectionable to us, cosmonauts, but it also damages the prestige of the Soviet Union and has a negative effect on the defense efforts of the countries from the socialist camp. Why is the Soviet Union losing its leading position in space research? A common answer to this question answer is… that the USA spend on space exploration much more than does the USSR. But the matter is not only funding. The Soviet Union also allocates significant funds for space exploration. Unfortunately, in our country there are many defects in planning, organization, and management of this work. How can one speak about serious planning of space research if we do not have any plan for cosmonauts' flights?...Manned space flights are becoming more and more complex and prolonged. The preparation of such flights

takes a lot of time, requires special equipment, training spacecraft, and simulators, which are now being created with huge delay and with primitive methods. To put it briefly, we need a national plan of manned space flights which would include the flight task, the date, the composition of the crew, the duration of the flight, the deadline for the preparation of a spacecraft and a simulator, and many other important issues of flight preparation.…[The letter then complains about the complicated system through which decisions must be made, resulting in a 'scattering of efforts and resources'] …Why have there not been enough ships built for our cosmonauts' flights? In any case, not because of the lack of funding. It happened because the leadership of the Missile Forces has more trust in automatic satellites, and it underestimates the role of human beings in space research. It is a shame that in our country, which was the first to send man into outer space, for four years the question has been debated whether man is needed on board a military spacecraft. In America this question has been resolved firmly and conclusively in favor of man… We do not intend to belittle the value of automatic spacecraft. But an infatuation with them would be, at the very least, harmful. Using the Vostok and the Voskhod spacecraft, it would have been possible to carry out a large complex of very important military research and to extend the duration of flights to 10-12 days. But we have no ships, nothing on which we could fly, nothing on which we could carry out a program of space research…Dear Leonid Ilyich! We know how busy you are and nevertheless we ask you to familiarize yourself with our space affairs and needs. The 50th anniversary of the Great October [Revolution] is approaching. We would like very much to achieve new, big victories in space by the time of this great holiday…"[129]

The letter was signed by the pilot-cosmonauts of the USSR: Yuri Gagarin, Leonov, Belyaev, Titov, Nikolaev, and Bykovsky. Kamamin passed the letter on to the Minister of Defense, but it likely never made it to Brezhnev and never received a reply. Several of the cosmonauts subsequently pushed for a meeting with top government officials to further their complaint.

Unfortunately for the Soviet flyers, their desire for more respect and deference coincided with a number of coming setbacks, including the death of Korolev (and a posthumous focus on the engineering and design side of the space program), the deaths of Yuri Gagarin and Komarov, and a series of launch failures after the mid-‘60s. The reputation of the unflappable Soviet cosmonaut had receded, and with it any chance of political influence.[130]

Voskhod 2 was launched in March of 1965. This mission again featured an important first: the first spacewalk. The craft weighed in at almost 12,000 pounds,[131] more than 60 times heavier than Sputnik in 1957. Part of that weight came from Voskhod 2’s “telescopic air lock” from which cosmonaut Alexei Leonov became the first man to experience space outside of a vehicle. Leonov was tethered to the Voskhod capsule, but otherwise floated freely in space after announcing to his comrade still in the capsule, “I’m pushing off! Man has walked out into space!”[132] Leonov experienced some difficulty upon reentering the capsule when the spacewalk was complete as his suit had expanded in space and he was now too wide to re-enter the narrow hatch and air lock. Fortunately, he was able to release some of the pressure from his suit and re-renter the capsule, albeit with difficulty.[133] Voskhod 2 also required the cosmonauts to manually fire their landing rockets to knock themselves out of orbit, as the retro-rockets designed for that purpose failed. This allowed them to return to Earth, but it was a difficult reentry that resulted in their landing in trees in the Siberian forest. The retrieval of the cosmonauts took over 48 hours.[134]

The Start of the Apollo Program

"Now it is time to take longer strides - time for a great new American enterprise - time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on Earth." – President Kennedy, 1961

A picture of Kennedy's address to Congress in 1961

The Apollo missions would require cutting edge rockets to launch state of the art modular spacecrafts to the Moon, while ensuring a successful reentry of the spacecraft back into Earth's atmosphere. When Kennedy outlined the vision in 1961, NASA did not yet possess the scientific or technological know-how for the spacecraft's return, and the spacecraft and rockets themselves did not exist yet.

At the beginning of the Apollo program, NASA wasn't even sure what the design would be for the spacecraft that would go to the Moon and back. At first blush, NASA's engineers assumed it would be easiest to directly launch a spacecraft to the Moon and equip it with boosters to launch it back to Earth. This approach, referred to as "direct ascent," seemed feasible to NASA because the Moon had no atmosphere, making ascent from the Moon

relatively easy.

Still, a minority of NASA employees advocated other designs. One design, known as “Earth Orbit Rendezvous,” would have attempted to assemble several pieces together into a spacecraft while in orbit. The “Earth Orbit Rendezvous” was used to assemble the International Space Station, but it was beyond the capabilities of NASA in the 1960s.

Meanwhile, another minority advocated what came to be known as the “Lunar Orbit Rendezvous” mission. Lunar Orbit Rendezvous required having a rocket launch a spacecraft consisting of three major components: a service module, command module and lunar module. The three modules would remain attached until the spacecraft began orbiting the Moon, at which point the lunar module detached and landed on the surface while the Command/service module orbited the Moon. The advocates for this type of mission argued that it would actually be the best option because it would require landing the least mass on the Moon. By the end of 1962, NASA was convinced that a Lunar Orbit Rendezvous mission was the best option.

Once NASA settled on using Lunar Orbit Rendezvous for the Apollo missions, they still had to design and construct the modular spacecraft and rockets. Right away, NASA faced a major logistical challenge; any lunar landing mission would require multiple crewmembers, but NASA had never developed a spacecraft that held more than one crewmember. To accomplish this, NASA designed a Command/service module. The service module would hold essentials like oxygen, water, and power, while the three astronauts would be in the command module during liftoff, orbit and reentry. The ultra-light lunar module, which was designed to descend and ascend to and from the Moon, could hold two astronauts. On ascent from the Moon, the lunar module would re-dock with the still orbiting Command/service module.

Designing the spacecraft wasn’t even the hardest part. NASA also had to develop rockets capable of first launching the modular spacecraft into Earth’s orbit, and then launching it toward the Moon. The Soviets struggled throughout the 1960s to design rockets up to the task, but NASA got it right with the Saturn V rocket, which to this day remains the most powerful launching rocket NASA ever used.

The companies that built each of the launch technologies epitomized the grand vision of a federal government and American public committed to funding gargantuan budgets that would send men on their way to the Moon. Each piece of hardware that would be used for a Moon mission, from the spacecraft, to the rockets, to the assembly buildings, transports, and operations headquarters, all developed into mammoth constructions. The crawler at the Saturn V rocket's base, "a great red-white-and-black skyscraper coming to life and advancing," transported the rocket to the launch pad, but essentially it was a launch pad that moved: Craig Nelson explained in *Rocket Men*:

> "As built by (Ohio's) Marion Power Shovel Company, the crawler took shape with eight tracks, each even by forty-one feet, with cleats like a Sherman tank, except that each cleat weighed a ton. Mounter over these eight tracks was the platform, bigger than a baseball diamond, on which the Apollo-Saturn V and it mobile launcher would ride VAB [Vehicle Assembly Building] to pad one mile per hour. The package weighed nine thousand tons, two-thirds cargo, one-third crawler."[135]

12,000 corporations came from the U.S., making up a total of 400,000 employees. Boeing built the Saturn V's behemoth bottom stage in New Orleans and barged the rocket across the Gulf of Mexico and across the canals of Florida. North American Rockwell in Seal Beach, California built Stage 2, which traveled through the Panama Canal. Stage 3 was built by Douglas in Sacramento, California, and was transported on Aero Supplies' specially modified Boeing Stratocruiser -- the "Super Guppy" -- to Kennedy Space Center. This same plane would carry the Command and Service Modules from North American's Downey, California plant, while the Lunar Module traveled by train from Grumman's factory in Bethpage, New York. [136]

The operation to build a Saturn rocket and put a spacecraft atop it involved the individual check of every part, and the manual for these checks surpassed 30,000 pages. Every machine was "tortured" in tests to produce 99.9% reliability. If the tests worked for every dial, switch, pump, light, fan, valve, and motor, Cape Canaveral could then return to its 1,700-page control plan.

300 pounds of monomethylhydrazine and nitrogen tetroxide were loaded into the Command and Lunar Modules, and by the time it was fully loaded for launch, the rocket and spacecraft weighed around 6.5 million pounds. Nelson notes, “6 million pounds of that weight was fuel and propellant: liquid oxygen (LOX) and kerosene for stage one; LOX and liquid hydrogen (LH2) for stage 2; and the hypergolics [self-igniting] for the tiny modules that in its final days would be the missions only spaceships.”[137]

Despite the fact America’s history of rockets, such as the Redstone and Titan, included notorious explosions on the launch pad, not a single Saturn ever blew up. That’s made all the more remarkable by the size, volume, and danger involved. As Kennedy rocket scientist Bob Jone explained, “You remained on the pad while the LOX prechilled, with xenon lights, and the wind blowing, and as those pipes chill, they scream...This thing is groaning and moaning and the hydraulic pumps are coming on...We would watch that thing ignite a beautiful, absolute, thunderous roar, zillions of horsepower, and you visualize them valves workin’ and them turbo pumps goin’ ch-ch-ch-ch-ch-ch. The thing if smokin’ and ventin’ and shakin’ and screamin’!”[138]

Apollo would carry men to the Moon partly because of the success of the Saturn. The rocket design signaled the intersection of a great many ideas about the future of American spaceflight and what kind of agency NASA would be. The short answer is civilian. Gemini used a military rocket, the Titan IIA, a heavy booster. The U.S. Air Force also had their hands all over the rocket, using it to launch spy satellites, and the military branch also planned to use Gemini, or Code Blue, as the missions would have been called. Military astronauts would have flown Geminis (I, II, and “Big Gemini”) and docked them with Air Force spy space stations, demonstrating just how much the Cold War mentality already infected much of the U.S. space program. While there was the “Space Race,” there was also the Rocket and Missile Race, and that larger competition between nations, which also involved a great deal of the same technology, signaled to some the growing danger of the militarization of outer space.[139]

There was not only a competition between nations, but one between American rocket and missile scientists as well. The debate about what to do with space, either to extend the arms race into Earth orbit or let the scientists

have their way, preoccupied the decision-making of President Eisenhower. On the eve of leaving the office of the presidency, he was faced with a decision to cancel the Mercury Program and not initiate a replacement. Advisors warned him of the “scientists,” saying if he allowed men like Wernher Von Braun to control the space program, scientists would want to explore the solar system.

The Saturn V rocket ahead of the launch of Apollo 10

The Saturn V rockets were truly gargantuan, standing nearly 350 feet tall and holding thousands of tons of fuel. These rockets could carry a payload weighing over 250,000 pounds into orbit, giving it the ability to launch the Apollo spacecraft into orbit in about 12 minutes at nearly 18,000 miles per hour. But that was just the beginning of the Saturn V’s duties. Once in orbit, the Saturn V still had to accelerate the spacecraft to nearly 25,000 miles per hour to allow the spacecraft to escape the Earth’s orbit and head for the

Moon.

Designing rocket engines that powerful was hard enough, but NASA had to design the Saturn V to accomplish its duties in multiple stages, because an Apollo spacecraft typically had to spend a few hours in orbit around the Earth before heading for the Moon. Thus, the Saturn V's first two stages would accelerate the spacecraft to about 15,000 miles per hour, while the third and final stage would enter the spacecraft into Earth's orbit at about 18,000 miles per hour. But this third and final stage also had to be capable of essentially restarting and reaccelerating to propel the spacecraft out of Earth's orbit and to the Moon at about 25,000 miles per hour.

The first challenge was to get the Apollo spacecraft into orbit, which required escaping Earth's atmosphere at about 18,000 miles per hour. From the launch pad, the first stage of the Saturn V rocket would accelerate the spacecraft to over 6,000 miles per hour in two and a half minutes before detaching and falling away. The second stage accelerated the spacecraft to about 15,000 miles per hour after six more minutes before falling away.

The Saturn V's third stage was the most crucial. First, it accelerated the spacecraft to 18,000 to enter it into orbit before shutting down. The spacecraft then orbited around the Earth to wait for the Moon's orbit to properly line up for the three day voyage to the Moon's orbit. The Apollo spacecrafts usually had to orbit around Earth at least once before it was time to head to the Moon. At the speed the spacecraft was going, it would only take a few hours to orbit the entire planet.

Next, the Saturn V's third stage had to reactivate itself for the "Trans Lunar Injection," accelerating the spacecraft to about 25,000 miles per hour to reach the escape velocity necessary to escape Earth's orbit. At this time, the lunar module attached to the command/service module, and once the spacecraft reached escape velocity, the Saturn V's third stage fell away on a different trajectory.

Once the spacecraft escaped Earth's orbit, it would take three days of cruising and a short engine burst known as the "Lunar Orbit Insertion" procedure to properly position the spacecraft to be captured by the Moon's orbit. NASA had mapped the Moon during previous missions, in order to

help choose the landing sites for the Apollo lunar modules. When the Moon captured the spacecraft, the spacecraft would complete several orbits around the Moon to properly line up the lunar module for descent.

To descend thousands of feet down to the Moon's surface, the lunar module had both an engine and thrusters that would allow it to maintain speed, control and direction. The lunar module would descend in a pirouette to help it descend straight. As Apollo 11's lunar module inadvertently proved, any incorrect timing or ill timed thrust would land a module several miles away from its intended destination, which could be the difference between a smooth landing or landing among boulders and craters. For most of the descent, the lunar module was automated, but the final stage of the descent required manual controls. When the descent stage was finished, it would fall away from the module, like the Saturn V rocket stages.

The Apollo astronauts usually spent between 20-36 hours on the Moon's surface, collecting several pounds of rocks and samples, and in later missions using rovers to travel around. When it was time to leave the Moon's surface, the lunar module would ascend back to re-dock with the command/service module. Since the Moon has no atmosphere, it was relatively easy for the lunar modules to ascend without needing powerful rockets like the Saturn V. The lunar module had an ascent stage with fuel propulsion engines to propel it back up to the command/service module. Once the lunar module rejoined the orbiter, the ascent stage was jettisoned, often landing back on the Moon.

The Moon's orbit is only a fraction of Earth's, so once the modules linked back up, the Command/service module was equipped with engines to propel it back toward Earth. The bigger concern for the return was that the modules had to reenter Earth's orbit at the proper angle to allow the planet to recapture it. Reentry into Earth's atmosphere subjects spacecrafts to temperatures of about 3,000 degrees Fahrenheit, so the module had an elaborate heat shield consisting of a mixture of dozens of panels, insulation and aluminum. A failure in any part of the heat shield system would be fatal.

Finally, it was time for the splashdown. The module had several "drogue parachutes," used for decelerating fast moving objects, which were used at about 25,000 feet. Those parachutes slowed the module down to about 125 miles per hour. Another set of parachutes would then slow the module down

to about 20 miles per hour before it hit the water.

Once the module splashed down, divers would deploy rafts to pick up the astronauts and anchor the module while a helicopter hovered overhead to collect everyone and everything. After being picked up, the returning astronauts would be quarantined for a period of time to study the effects the mission had on their bodies.

A picture of the Apollo 1 crew practicing the splashdown and exiting the module

Most people can name Apollo 11 as the first mission to land men on the Moon, and a critically acclaimed film about Apollo 13's harrowing mission was released in 1995. As a result, the rest of the Apollo missions have been greatly overshadowed, including Apollo 8, despite the fact Apollo 8 accomplished several firsts and ultimately made Apollo 11 possible. However, none of those missions would've taken place the way they did without the bitter lessons learned by Apollo 1.

Cape Canaveral Air Force Station Launch Complex 34, site of the Apollo 1 disaster

Picture of the arrival of the Apollo 1 command module

"On the morning of January 27, 1967, a test of SIC 012 commenced. The purpose of the test was to verify systems operation in a simulated launch and to exercise countdown procedures in preparation for actual launch. The test was identified as a Space Vehicle Plugs Out Integrated Test OCP FO-K-0021-1 in which the spacecraft would be electrically disconnected from the Ground Support Equipment (GSE) by removing the umbilical connectors normally disconnected at the time of launch." – Passage from the *Report of the Apollo 204 Review Board*

In a nation that was becoming increasingly bogged down in Vietnam and where Civil Rights marchers and leaders were regularly targeted for violence, the space program had become for many a shining beacon, giving hope to a nation in desperate need of something to believe in. Just a few days before the Apollo 1 disaster, a *United Press International* article had announced, "Apollo 1 astronauts Virgil (Gus) Grissom, Edward White and Roger Chaffee are set to ride a powerful Saturn rocket into orbit Feb. 21 to inaugurate the manned portion of the Apollo men-to-the-moon program. The launch date, made official Monday by the U.S. Space Agency, misses by one day the fifth

anniversary of America's first orbital venture—the 5 1-2 hour flight of John Glenn in the ‘Friendship 7’ Mercury capsule.”

White, Grissom, and Chafee posing with a model of the Command/service module

A picture of the Apollo 1 crew and the backup crew: David R. Scott, James A. McDivitt, and Russell L. Schweickart

Known officially as AS-204, the Apollo 1 spacecraft was designed to be the first manned Command/service Module to orbit the earth for any length of time, perhaps as much as two weeks, and the confidence that both NASA and the American people had in the program could be seen in the *Command Service Module System Handbook*, published less than two weeks before the incident. According to that publication, the module had "been prepared by the Flight Control Division, Manned Spacecraft Center, Houston, Texas, with technical support by North American Aviation" and contained the following stern warning: "Information contained within this section represents the Command Service Module Systems for the AS-501 Mission as of January 16, 1967. Information as shown reflects spacecraft systems with major emphasis on material for use by Flight Controllers in real time; however, caution

should be exercised in using these systems drawings for any purpose other than flight control." Ironically, although it was more than 300 pages long, it contained no information on emergency exit systems for the module.

The three men who were part of the launch rehearsal that day knew full well the potential danger of the mission and even mockingly prayed to a model of their command/service module in one parody of their official mission portrait. The commander of the mission was Virgil Grissom, known to his friends and the American public as Gus, and when asked about the danger of space travel a month before the disaster, he replied, "You sort of have to put that out of your mind. There's always a possibility that you can have a catastrophic failure, of course; this can happen on any flight; it can happen on the last one as well as the first one. So, you just plan as best you can to take care of all these eventualities, and you get a well-trained crew and you go fly." After his death, one Associated Press article observed, "For Air Force Lt. Col. Virgil I. Grissom, the first Apollo mission would have been his third trip into space, a distinction no man today can claim. … Some called Gus Grissom a hard-luck astronaut. As one of the famed original seven Mercury spacemen, he became the second American to fly in space. Taking a 15-minute sub-orbital flight July 21, 1961 he had to swim for his life when his tiny spaceship, Liberty Bell 7, blew its hatch and sank. On March 23, 1965, he and Navy Cmdr. John W. Young had the honor of launching the United States into its highly successful Gemini program with a three-orbit flight in Gemini 3. Grissom, 40, was a short man with a deep, business-like voice who wore his hair in a crewcut. Born in Mitchell, Ind., he once said he decided as a sixth grader there, watching airplanes overhead, that the flying business was for him. The Air Force turned him down because he was too young, only 17, when he first tried to enlist as a fighter pilot in World War II. He got on duty a year later, but as a typist. He married his high school sweetheart, Betty Moore, during his first leave. After the war he worked as a fry cook in a hamburger shop, while his wife worked as a telephone operator, and graduated from Purdue University. During the Korean War he finally won his wings, going on to fly 100 missions and win the Distinguished Flying Cross. He became an astronaut in 1959."

With Grissom on that fateful morning were Edward White and Roger Chaffee. Of White, the same reporter wrote, "The son of an Air Force

General, White, 36, was born in San Antonio, Tex., but lived there only a short time. As a ‘military brat’ he was at a loss to call any place his home town. He was graduated from West Point and later earned a master's degree in aeronautical engineering from the University of Michigan. Still later he attended test pilot school at Edwards Air Force Base, Calif. A deeply religious man, White, a Methodist, attended church regularly. He kept his six-foot frame in top physical condition. In fact, he ranked No. 1 in physical aptitude in his class of 1952 at West Point, and set a 440-yard hurdle record. He married the former Patricia E. Finegan of Washington D.C., and they had a son and a daughter.”

According to the article, Chaffee was born to be a pilot and “inherited his love for the air. His father, Donald Chaffee of Grand Rapids, Mich., is a former barnstormer who flew at county fairs in an open cockpit airplane. The astronaut was slight, dark-haired man who at 31 already had begun to gray. Coworkers praised him as a smart engineer. … Chaffee held a bachelor's degree in aeronautical engineering from Purdue and chose a Navy career through the ROTC program. He met his wife, Martha Horn of Oklahoma City, Okla., while at Purdue. Chaffee became an astronaut with the third group named in 1963 after a tour of duty at the Jacksonville, Fla., Naval Air Station. Part of his duty there was taking pictures of Mercury Spaceships as they soared aloft from Cape Kennedy, Fla.”

A picture of the men pretending to pray to the module

The nation had much to look forward to with this latest venture, as Apollo 1 would carry a television camera, designed to send video back to NASA and to let the astronauts broadcast portions of their flight to audiences on earth. This was a vital part of NASA's public relations campaign to keep their very expensive budget intact. As the Vietnam War continued to heat up and the War on Poverty became a popular cause, some in the country were beginning to question why the government was spending so much money to send a few men into space.

The Apollo 1 Tragedy

A picture of the crew training in a simulator

A picture of the crew entering the module in a previous test in 1966

"The Plugs-Out Test was initiated on January 27, 1967 at 12:55 GMT (7:55 a.m. EST) when power was applied to the spacecraft for this test. After completion of initial verification tests of system operation the flight crew entered the Command Module. … The Command Pilot noted an odor in the Spacecraft Environmental Control System suit oxygen loop and the count was held at 18:20 GMT while a sample of the oxygen in this system was taken. This odor has been determined from subsequent analysis not to be related to the fire. … Communication difficulties were encountered and the count was held at approximately 22:40 GMT to troubleshoot the problem. … From 22:45 GMT until about 22:53 GMT the flight crew interchanged equipment related to the communications systems in an effort to isolate the communications system problem. … During the troubleshooting period problems developed in the ability of various ground stations to communicate with one another and with the crew. None of the communications problems appear to have had a direct bearing on the fire." – Passage from the *Report of the Apollo 204 Review Board*

Entering 1967, the Apollo project was going well. In fact, during the previous month, NASA had decided to cancel one of its major test flights, ruling that such an expensive trip was not needed. Instead, the three man crew could focus on preparing for their February 21 launch.

On the fateful morning of January 27, they were performing the Plugs Out Integrated Test. According to the report of the Apollo 204 Review Board, "The purpose of the Space Vehicle Plugs-Out Integrated Test, Operational Checkout Procedures (OCP) FO-K-0021-1, Spacecraft 012 is to demonstrate all space vehicle systems and operational procedures in as near a flight configuration as is practical and to verify their capability in a simulated launch. System verification is performed, an abbreviated final countdown conducted and a flight simulation made. All communication and instrumentation systems are activated and proper measurements are monitored at appropriate ground stations. At the start of the simulated flight, umbilicals are disconnected and the spacecraft is on simulated fuel-cell power. Specific objectives of this test for Spacecraft 012 as stated in the Final Procedure Document were:
a) To verify overall spacecraft/launch vehicle compatibility and demonstrate proper function of spacecraft systems with all umbilicals and Ground Support Equipment disconnected.
b) To verify no electrical interference at the time of umbilical disconnect.
c) To verify astronaut emergency egress procedures (unaided egress) at the conclusion of the test."

At first, everything seemed to be functioning normally. The test began at 7:55 a.m., but when the astronauts entered the module and took their seats around 1:00 p.m., Grissom complained about smelling a strange odor that he described as a "sour smell" coming from his oxygen supply. This resulted in the simulated countdown being stopped at 1:20, but after checking it out, the men in charge determined that it was nothing to be concerned about and authorized the tests to continue. The countdown started again around 2:45 in the afternoon. When the countdown resumed, support crew stepped forward to secure the three hatches which would ultimately trap the crew in the sudden inferno.

Lewis Curatolo, from North American Aviation, helped the astronauts into

their seats that fateful day and later reported, “At approximately 1300 I notified the Test Conductor and Test Project Engineer that we were ready to perform Crew ingress. The Suit Technician and the Spacecraft Technician performed the pre-ingress layout of the cockpit and couches. This procedure consists of laying out the pilots seat and shoulder harnesses, and routing of the 02 umbilical hoses. … After completion of the Crew ingress we proceeded with Hatch closeout, and Cabin purge, as directed by the Environmental Control System engineer and Test Project Engineer. … At this time we were directed to proceed with outer hatch and Boost Protective Cover closeout. We installed the outer crew hatch and started with the Boost Protective Cover installation but experienced some difficulty in getting the Boost Protective Cover to lock in, so I notified the Test Project Engineer and asked for an Interim Discrepancy Report. The Boost Protective Cover was left unlatched and we were instructed by the Test Supervisor and Test Conductor to clear the White Room. I followed the Test Conductor's instructions and at this point (1730) the 2nd shift Pad Leader (Don Babbitt) relieved me.”

A picture of the hatch design used on Apollo 1

As if there hadn't been enough omens, the countdown had to be stopped again at 5:40 due to communication problems. The crew was wired with a live microphone that they needed to be able to turn off from time to time, but the microphone could not be turned off. While this problem was being dealt with, other activities related to the countdown continued, and at 6:20 p.m., with all other countdown functions completed, NASA decided to hold the launch clock at T-10 until the problem with the microphone could be fixed.

As much as investigators looked back again and again at the crew's final moments, no one could ever determine what exactly went wrong. The Review Board later noted, "From the start of the T-10 minute hold at 23:20 GMT until about 23:30 GMT there are no events that appear to be related to the fire. The major activity during this period was routine troubleshooting of the communications problem. The records show that except for the communications problem, all systems were operating normally during this period. There were no voice transmissions from the spacecraft from 23:30:14 GMT until the transmission reporting the fire which began at 23:31:04.7 GMT (6:31:04.7 p.m. EST)."

As far as what was going on inside the module or in the heads of those who were unwittingly facing imminent death, there is no evidence to indicate that they had any concerns. NASA took the health of its astronauts seriously and wired them with numerous sensors designed to immediately detect any sort of physical problem that might compromise the mission. Not only did these monitors constantly transmit data back to Mission Control, they also left behind records that showed how the men were doing. According to those who examined these records, "During the period beginning about 30 seconds before the report there are indications of crew movement. … There is, however, no evidence as to what this crew movement was or that it was related to the fire. The biomedical data indicate that just prior to the fire report the Senior Pilot was performing essentially no activity (or was in the baseline 'rest' condition) until about 23:30:21 GMT [6:30:21 locally] when a slight increase in pulse and respiratory rate was noted. At 23:30:30 GMT the electrocardiogram indicates some muscular activity for several seconds. Similar indications are noted at 23:30:39 GMT. The data show increased

activity but are not indicative of an alarm type of response. By 23:30:45 GMT, all of the biomedical parameters had reverted to the baseline 'rest' level."

Another sensor that registered movement was the gas chromatograph cable, which would have run to the gas chromatograph had it been installed in the command module. According to the report, "When the gas chromatograph is not connected, the cable acts as an antenna. Thus, changes in the electromagnetic field within the spacecraft are sensed when the cable is approached closely, touched or moved or voltage fluctuations occur in other equipment. Variations found in the signal level from the gas chromatograph cable at earlier times in the test have been correlated with either crew movement or voltage transients when equipment was turned off or on at these earlier times. The variation at 23:30:50 GMT, may have resulted because it was touched or approached by the crew since there does not appear to be any voltage transient condition at this time which could have given the observed signal."

In essence, investigators could find nothing in the data to indicate at that point in time that the astronauts of Apollo 1 had only seconds to live.

Perhaps the only positive thing that can be said about the tragedy was that when the end came, it likely happened very quickly. At 6:30:54.8 local time, the machines monitoring the module noted "a significant voltage transient" in the AC Bus 2 voltage, and 10 seconds later, the men indicated there was a problem. 30 seconds after that, they were likely dead, or at least unconscious.

The tape recordings made from the astronaut's microphones show that they likely suffered for only a few seconds, though how long that time period seemed to be to them is beyond human imagination. According to an analysis made of the tapes:

> "The total time duration of these two transmissions was brief, lasting 17.1 seconds; the first lasted 5.3 seconds and the second lasted 5.0 seconds, with a 6.8 second period of no transmission between… Except for a portion of the first transmission, which is quite clear, the remainder of the first and second transmission is

not clear and it is impossible to define exactly what was said by the crew. … [The first] transmission began at 23:31:04.7 GMT [6:31:04.7 local time] with an exclamatory remark. … Most listeners believe this initial remark was one of the following: ‘Hey ‘ ‘Fire ‘ ‘Break ‘ Most listeners believe…that this transmission was made by the Command Pilot. This remark is followed by a short period of noise (bumping sounds, etc.). … The second portion of this first transmission begins at 23:31:06.2 GMT with an unclear word. Most listeners believe the first to be one of the following: ‘I ‘ve’ ‘We’ve’ The remainder of this transmission is quite clear and is: ‘...Got a fire in the cockpit’, followed by a clipped word sounding like ‘VHEH’, which ended at 23:31:10 GMT. Many listeners believed this transmission to have been made by the Pilot. … The entire second transmission is somewhat garbled [and] is subject to wide variation of…The following is a list of some of the interpretations that have been made:

(1). ‘Fighting a bad fire - Let’s get out ..... Open ’er up.’

(2). ‘We’ve got a bad fire - Let’s get out ..... We’re burning up. ‘ ‘I’m reporting a bad fire .... I’m getting out..Oh, AAH.’ (Scream)”

A. R. Caswell, who was at one of the television monitors, later testified, “At approximately 18:30 Eastern Standard Time my attention was directed to the monitor by OTV technician Gary Propst, his remarks was that there is a fire in the capsule. … Upon directing my attention to the remark by technician Propst, I observed on the white room camera, a flickering of flame inside of the capsule on the left side of the port hole. This flame flickered for some time I would estimate 15 - 20 seconds and then it spread across almost the full face of the port in the hatch cover. … Reverting my glance back again to the camera covering the hatch porthole I would estimate that some 30 to 40 seconds elapsed before the flames reached a very high proportion, in which there was nothing visible but a white searing type of flame inside the cockpit. The period specified from 15 to, or rather to, 30 to 40 seconds was subsequent to my initial time that I observed the fire in the hatch. The fire, the flames that I saw were definitely inside the capsule, there was no fire around the hatch at this particular point in time.”

The men had trained for such an emergency and seem to have sprung into action to try to survive. The protocol called for White, occupying the center seat, to unlatch the inner hatch, and video recorded by the television camera gave the impression that he at least tried to do this. Caswell testified, that "when we first noticed the flames at the cockpit it appeared on the left side facing the hatch cover. And it was during this initial period that we detected what we feel was motion by some movement of the helmet of the center crew member. And then seconds perhaps 10 to 15 seconds the flames had spread across the face. …I did notice what appeared to be motion of the center crew man upon the initial outbreak of fire as my observation was directed to it. And then it appeared within perhaps 20 seconds, the flames had obscured a good view or any type of view of the crew member because they were spread across the face of the porthole. As time progressed, perhaps to 45 seconds to a minute, the intensity of the flames greatly increased to where they appeared to be white hot. This is confined to inside the spacecraft."

One thing that has troubled investigators for years is the testimony of Propst, who also watched on his video monitor as events unfolded but gave a very different time line. According to Propst, "At about 1830 one of the Astronauts said, 'Fire in the cockpit', this was followed by a scream and then silence. … Immediately I looked over to our camera 24 which is located inside the White Room. …as soon as my eyes caught sight of the camera 24 monitor I noticed a bright glow inside the spacecraft, however, I saw no flames. Just a split second later I saw flames go past the porthole. The flames were not in the order of an explosion but were, in fact, that of something just burning. The fire increased steadily during the next two to two and one half minutes. … The first thing I saw was what appeared to be the center Astronaut's arms reaching above his head toward the hatch. There followed a great deal of motion as his arms seemed to fumble with something and then quickly reach back for it. From time to time the top of his helmet could be seen. About 15 seconds after the cry of fire, I saw more arms in front of the porthole seemingly coming from the left. Looking further back into the spacecraft, I could see the legs of the center Astronaut moving about. The movement inside the spacecraft lasted about 2 minutes before the flames began to block the view. At first the flames were behind the Astronaut's arms toward the center of the spacecraft and then spread forward to the area of the

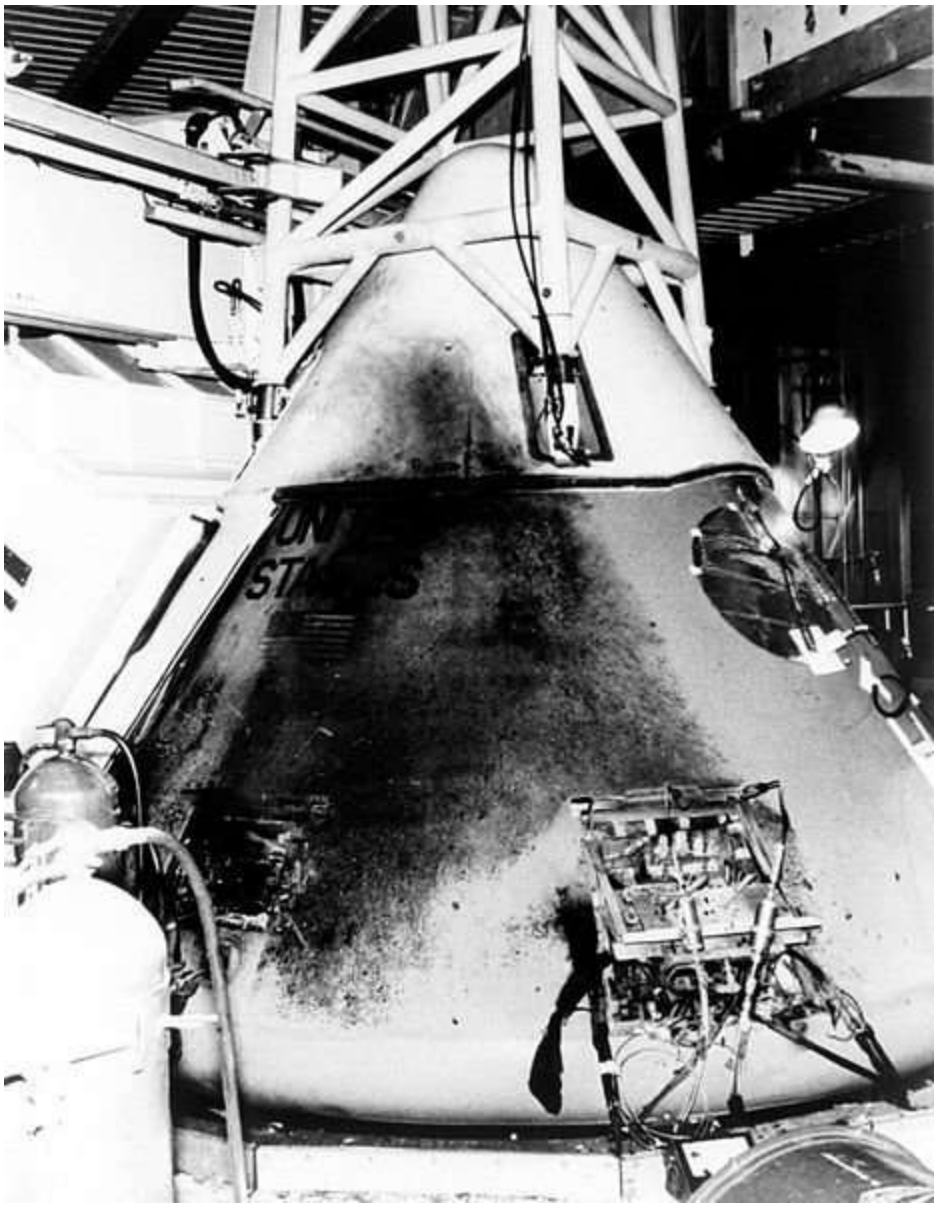
hatch."

As they watched the scene unfold, Propst and his co-workers speculated about exactly what they were seeing, trying as people so often do during a disaster to wrap their minds around an incredible and unbelievable situation. He continued, "During the entire time that I watched the Astronauts' moving, their spacesuits were silver in color with no signs of being burned or charred. I think it noteworthy that no one entered the White Room until it had become smoke-filled some minutes later. Had anyone entered and gone near the spacecraft they would have been visible on the TV camera. .. I know that my times are very near accurate because I remember saying to others that had gathered in the area of the monitor: 'Blow the hatch, why don't they blow the hatch?' One person that was near said that the spacesuits would protect them from the heat until they could get out. A short conversation then took place concerning how long and how much the suits could protect them from the fire. Also comment was made on why no one had entered the White Room as yet. During the time of this conversation the White Room was still clear and the Astronaut's motion still visible."

Since White likely passed out before he could open the hatch, it was left to those on the outside to try to conduct a rescue, but they were plagued with problems that prevented them from offering any timely help. When investigators asked how much time actually passed before the astronauts were reached, Donald Babbitt of North American Aviation testified to the Review Board, "The time period in here I can only estimate as 5 to 15 seconds. I heard on the head set…Mr. Chaffee say, 'There is a fire in here,' (or words to this effect). I ordered the mechanical lead man, Mr. Gleaves, to 'Get them out of there' (meaning remove the hatches and get the crew out of the Command Module)."

However, less than 20 seconds after the fire in the module broke out, the flame breached its exterior and began to spread. At this point, Babbitt realized that his own life was in danger because if the fire spread out of control, it might reach the rocket fuel and cause a detonation that would've leveled the entire launch pad. He recalled, "I started to turn toward the Communications Box (on my left), when out of the corner of my eye, I saw flame come out from under the boost near the steam duct. I almost completed

my turn when I was hit by a concussion or sheet of flame (I don't remember hearing an explosion) and was pushed toward the communication boxes. My next thoughts were to get out of there. (I never had time to notify the blockhouse). I went to the umbilical (White Room) arm, [into which the hatch should open] and went across it to the umbilical tower where I encountered three of the spacecraft mechanics and an elevator talker who had a head set. I told the talker to inform the test supervisor that we were on fire and that I need firemen, ambulances, and equipment. With the three mechanics (Messrs. Gleaves, Hawkins, and Clemmons) we grabbed the only C02 bottle available and went back to the White Room to try to remove the hatches. The smoke and heat was so intense that we could only spend a short time in the White Room (possibly 1-2 minutes). After several trips back and forth Mr. Gleaves almost passed out due to smoke inhalation so I ordered him to stay out, which he did but for only a short time."



Pictures of the charred module

Crises, especially when being handled by highly trained personnel, typically begin as a highly structured and detail-oriented exercise but often

progress to more and more desperate measures, as the best trained among the respondents exchange procedures for experience and initiative. So it was in the minutes that followed the Apollo 1 fire. James Gleaves, one of the first men to approach the module, later reported that “a gentleman named L. D. Reece found the oxygen masks and was handing out the oxygen masks. We had trouble locating the strip of tape on the bottom because they were painted the same color as the connector. And several times, one, two, three or four of us returned without masks and stayed as long as we could, then finally Babbitt and myself entered the white room after the fire had been extinguished by Jerry Hawkins and on all fours I crawled. I found the tool to remove the ablative hatch. I removed the ablative hatch and I didn't have a mask on at this time and I just couldn't take it no longer so I returned out and gave the tool to Jerry Hawkins, Steve Clements and L. D. Reece. And they removed the ablative hatch and L. D. Reece threw it out on level A8 and then these guys, also they had masks on, they removed the inner hatch and it was so hot they just let it drop down under the couch. So they come back out and I in return went in and kicked the inner hatch and it sort of fell down under the couch. I pushed but it was still hot and inside the spacecraft was black and filled full of smoke. You couldn't see anything at all. So I returned to A8 and out of the white room and got a flashlight and went back in and tried to see inside the spacecraft but the heat was too great and the smoke was too bad so we returned out on A8 and we continued to go back in. And as far as I can remember it took maybe 10 or 15 minutes for any fireman or any help to get to us up on the swing arm.”

Within a few minutes, the fire nearest the module was under control, and Babbitt was placed in the unenviable position of opening the hatches. Babbitt was perhaps the first person to understand that due to a flawed design that would be discussed for decades, the men trapped inside never really had a chance of escape. Due to the increase in pressure inside the cabin during the fire, the hatches would never have been able to fully open. Babbitt recalled, “After the smoke had cleared some, I could see that the Spacecraft Technicians and Quality Control (NASA and NAA) had been able to get back into level A-8 and were fighting fires with everything available, so I got some more men and continued as best we could (because of the smoke and heat) to remove the hatches. We attempted to both remove the inner hatch or

lower the hatch down inside the Command Module. We were not successful in removing the inner hatch and could only lower the hatch about 75 to 80% of the way because of obstructions. I was at that time only able, again because of the smoke which was considerable, to observe only two of the flight crew but could not recognize who it was. The inner hatch was extremely hot and we could only handle it with the handles attached to the hatch. My observation at the time of hatch removal was that the flight crew were dead and that the destruction inside the Command Module was considerable."

There was little he could now do for the men who only moments before had been his co-workers, but Babbitt carried on with his duty before finally succumbing to his own injuries. "After informing the test supervisor of what I had observed (while adhering to security guidelines wherever possible) and continued to direct the crew in putting out the fires. I asked the senior Pan American firemen to specifically check the Launch Escape Motor for hot spots and general heat. I was relieved by Mr. Curatolo, NAA 1st shift pad leader. I proceeded down the umbilical tower elevator, met the two NASA doctors and briefed them on what they would find. I then proceeded to the Pan American Dispensary, with a short stop at the NAA Shop Trailer, for treatment and checkup. I was treated for smoke inhalation, flash burns, and eye irritation, and ordered to remain overnight."

On February 8, Babbitt was called back to testify as to what he observed when he opened the hatch. He described the gruesome scene in vivid detail:

> "When the inner hatch was first lowered, the only thing that I could observe was smoke inside. We could only feel the flight crew. We could not see them very well as I could tell. As the men working with me went out because they'd been in the smoke quite a while, I went back in, oh, approximately one minute or a minute and a half later; and all that I could observe was what appeared to be Mr. White laying on his back with his arms over his head, appeared to be reaching for the hatch or in something in that vicinity. I also observed what appeared to be Mr. Grissom laying with one of his arms through and appeared to be reaching in the direction of the hatch also.

> I went out again for a short bit and came back in maybe thirty seconds after that. I could see a little bit more. The smoke had cleared some more. All that I could really see was, oh maybe, to the waist of Mr. White. …I at first got the impression that they were off the seats; and then I got the impression that no they were on the seats. It appeared that their suits were shredded. I could see bare skin. … The crew appeared to me to be in their normal, in-flight position. I could only see what appeared to be Mr. Grissom's left arm reaching through Mr. White's arm. I could not see his body that well, but it had the appearance of being in its satisfactory or its normal position. I did not observe Mr. Chaffee because I was a little bit too far to the right of the hatch and could not see him. Mr. White appeared to me to be as I say, laying in his normal boost position. I could not tell whether his head rest was up or down. In fact, I couldn't even see his features because of the, what appeared the smoke or soot blackened face plate on his helmet."

Lewis Curatolo, who had earlier helped the men into their seats and himself helped seal the hatches, recalled, "I observed that the body of the Senior Pilot was wedged between the Crew Couches and the hatch bulkhead; the Command Pilot was positioned in the center couch with his body partially hanging over the center couch. The Pilot was in a reclining position in the Pilot's Couch. I observed that the Command Pilot's leg pans were in the rest position, the Senior Pilot's leg pans were in the boost position, and the Pilot's leg pans were in the full down position."

James Burch was one of the firemen sent over that evening, and with the fire already extinguished, their first priority was to try to rescue the astronauts. He later testified, "From the time we received the call, I would estimate that we got to the gantry in around five or six minutes. We took the slow elevator up. The fast elevator was out. It took us approximately two minutes to reach the top of the gantry. Assistant Chief, McMillan, Bob Batts the Crew Chief, Rector - Fire Fighter, Dawes the Fireman and myself reached the top. As we reached the top, I went around to the side of the capsule where the man on the headset was hollering that the men were still inside the capsule. I was not sure who was inside, and I asked him specifically who was inside the capsule. He said that the astronauts were still inside. There were

about five or six technicians standing on the gangway; and as I looked into the hatch, there were two men coming out that had been working on the hatch. Me and one other fireman, I'm not sure who he was - it, I believe, was Rector, we proceeded in without a mask and tried to take the hatch cover off. It was loose but was still intact. As we picked it up and down, we couldn't move it. We jammed it back and forth quite a few times, but the smoke was thick and we did not know how to take it off."

Burch's reference itself would confuse many by giving some the impression that the hatch was still on when the firemen arrived. However, a careful reading of his remarks shows that the hatch was open and Babbitt and Cuartolo were emerging when he arrived. Thus, he was not trying to open the hatch but remove it. Many other questions would also be asked about why there were not items in place when they were needed, as well as why the "fast elevator" was not in service that day. While corrections would be made, they obviously came too late for the three men trapped inside the module.

Meanwhile, those around them could only do the best they could under the circumstances. Burch continued, "I would say we stayed in around thirty seconds before we had to leave to get a mask because the smoke was too thick. Upon going out on the gangway, one of the men out there gave me a mask - gas mask - I put it on and entered the room again with one of the technicians. We then tried again to take the hatch cover completely off. He was trying to tell me that you had to drop it down and push it in and turn it sideways to get it off. We worked quite a few minutes on trying to do that. It seemed like minutes...I'm not sure how long it was. But, anyway, we could not get it; and we were choking up considerably on the smoke and fumes that were in there. We then went back outside, got a breath of air and then returning back, we tried again to get the hatch cover off. I know I choked up two or three more times, and the man that was with me also choked up. It wasn't but just a few seconds that he choked up so bad that he turned around and left."

In spite of the physical suffering they personally experienced that day, nothing was as frustrating as the problems they had trying to gain entry into the module, and nothing as disturbing as what they found once they made it inside. Burch remembered, "Frantically, I was still working on the hatch

cover. I was shaking it, turning it, doing everything in the world I could to get it off. Then, just all at once it seemed to fall back on me; and as I turned with the hatch in my hand halfway off - someone was there to grab hold of one of the handles; and we set it back away from the hatch. Then, I took a flashlight, I laid over inside the capsule trying to see the bodies or anything that I could see. The inside was burnt considerably, there were wires hanging down. I shined the light completely around inside the capsule, and I couldn't see anything except burnt wires hanging down. I then backed out, told the man on the headset, I said, 'There's no one in there.' He said, 'There has to be someone in there. They are still in there. Get them out.'"

At this defining moment, Burch faced what was likely the worst moment of his career. "I re-entered, looked around again; and I still didn't see anyone but there under me was a boot. I grabbed the boot, pulled it, it came off. There wasn't anything there except just a black mask. Then, I just grabbed an armload of I don't know what; but it seemed like it was coming loose. The first thing I knew I had a pair of legs in my hand. The hair was still intact on the legs. They were not, burnt bad. In fact, they were not burnt at all it looked to me like. I checked to see if the skin was going to slip, it wasn't so I reached my arm through both legs, under both legs, and pulled up just as hard as I could pull. The body moved probably six inches or less, but I knew I couldn't move him out. I then backed off to see just exactly what I did have. I could see that the, just the knees were sticking up on the only person that I could recognize. As far as the rest of it, it was just a black mass and I couldn't tell which way the bodies were laying or anything. I then backed out. I told the man on the headset, 'They are all dead, the fire is extinguished. The only thing we need now is to get the smoke cleared out, and then we can tell more about it.'"

In concluding his remarks, Burch offered a final observation about his experience, and how he completed his search: "As I leaned in with the light, I crawled into the hatch and went as far as my knees, I looked around with the flashlight all the way to the back of the capsule; and I could not see anyone. At the time, the knees of the top man must have been under my stomach because I drew myself back and just grabbed a hand full of which just had to be a burnt suit and came up with a pair of knees. They had to be right at the hatch. As I leaned in, I must have been lying right on top of the knees. I could

not see anyone in the back, but I could see full vision all the way to the back of the capsule."

While each witness would have his own opinion about how much time had passed at this point, audio recordings would later confirm that less than 10 minutes passed between the time of the first fire report and the moment that the final hatch was opened.

The doctors arrived a few minutes later, and while everyone who had seen the bodies had to figure it was too late, there might have been some hope among the medical professionals that something could still be done before they actually arrived. However, any hope was soon gone. According to the medical panel, "The two NASA physicians and the Pan American physician then proceeded to the spacecraft. The time of arrival at the White Room on the 8th level is estimated at 6:45 pm EST (23:45 GMT). When the physicians first arrived, the hatches had been removed, the spacecraft was still smoldering, pyrotechnics had not been safetied and smoke was too thick to spend any time in the vicinity without a breathing apparatus. After a quick evaluation, it was decided that nothing could be gained by attempting immediate egress and resuscitation. By this time, some 12 to 15 minutes had elapsed since the fire began. It was evident that the crew had not survived the heat, smoke, and thermal burns. Conditions within the spacecraft (later confirmed by toxicological determinations) were such as to produce high levels of carbon monoxide (CO), carbon dioxide (C02), and other toxic gases and irritants. Also, oxygen was markedly depleted after the rupture of the spacecraft. These conditions would have necessitated institution of resuscitative measures within a very few minutes, since under optimal conditions, resuscitation commenced more than four minutes after cardiac arrest is usually unrewarding."

Knowing there was nothing they could do, the doctors joined the growing crowd of those lingering around the disaster area. "The three physicians then returned to ground level until adequate ventilation could be established. Shortly thereafter, they returned to the spacecraft with equipment for an attempted removal. After trying to remove the Senior Pilot by cutting his suit umbilicals and electrical connections, it became apparent that extensive fusion of the suits to molten nylon from the spacecraft would make removal

very difficult. For this reason, it was decided to discontinue efforts at removal in the interest of accident investigation and attempt to get photographs of the spacecraft and relative positions of the crewmen before evidence was disarranged. The two NASA physicians remained in the vicinity of the spacecraft while the Pan American physician returned to ground level. NASA Security arranged for photographic coverage. After this was accomplished, one of the NA SA physicians returned to the blockhouse for approval to resume egress operations. Approval was received from Major General Samuel C. Phillips, U.S. Air Force/Apollo Program Manager, shortly after midnight, local time, and egress was begun at approximately 12:30 am EST (05:30 GMT), January 28, 1967."

As mentioned above, the doctors performing their duties knew that there would be an extensive autopsy, and that the findings had the potential to prevent a future disaster. Therefore, though exhausted with grief and effort, they made sure the astronauts' bodies made it safely into the waiting ambulances for transport to their next destination. "The Pan American Dispensary log indicates that the ambulance with the Senior Pilot arrived at the Pan American Dispensary at 1:17 am EST (06:16 GMT). The ambulance with the Command Pilot arrived at 1:35 am EST (06:35 GMT) and the ambulance with the Pilot arrived at 2:08 am EST (07:08 GMT). Therefore, removal of the crew took approximately 90 minutes and was completed about seven and a half hours after the accident. The crewmen were removed to the Bioastronautics Operational Support Unit for postmortem examinations at 4:17 am EST (09:17 GMT)."

Few forms of death strike terror in the hearts of people like that of being burned alive. In the mid-1960s, when many homes still used fire as a source of heat for at least part of the year, these types of deaths were more common and thus more feared, so when word spread that the astronauts had perished in a blazing inferno, there were both gasps of horror and questions about how much they suffered and for how long. In fact, such questions continue to this very day among those who never accepted NASA's findings.

That said, the doctors were clear when they wrote that, in all three cases, "carbon monoxide poisoning is the most significant finding." The doctors went on to say that Grissom was the most severely burned, "estimated as

60% total body surface area (36% third degree).” White suffered burns “estimated as 48% total body surface area, (40% third degree),” and Chaffee was burned on “29% total body surface area (23% third degree).” While none of the men would have died immediately from the burns, the doctors admitted they were “considered as a contributory cause of death.”

Despite the horrific extent of the burns, it still seems unlikely that any of the men suffered for long. In each case, the medical panel concluded, “Loss of consciousness was due to cerebral hypoxia due to cardiac arrest, due to myocardial hypoxia. Factors of temperature, pressure and environmental concentrations of carbon monoxide, carbon dioxide, oxygen and pulmonary irritants were changing at extremely rapid rates. … The combined effect of these environmental factors dramatically increased the lethal effect of any factor by itself. It is estimated that consciousness was lost between 15 and 30 seconds after the first suit failed. Chances of resuscitation decreased rapidly thereafter and were irrevocably lost within four minutes.”

No one will ever know the sequence of events with certainty, but the medical panel did come up with something of a timeline indicating that, based on the biomedical readings, the astronauts became aware of the fire at around 6:31:04 and that at least one of the men was still conscious 42 seconds later. Beyond that, the panel also found that the “Command Pilot had moved from his normal position after the onset of fire. The suit failed prior to rupture of the pressure vessel (the time of spacecraft rupture has been estimated by Panel 5 to be 6:31:19 pm EST (23:31:19 GMT). … The Senior Pilot did not leave his position until his restraining straps were burned through. He had moved from his normal position after the onset of fire. … There is no evidence that the Pilot moved from his normal position after the start of the fire. This is consistent with the emergency egress procedure which calls for the Pilot to be the last to the leave the spacecraft.”

After extensive investigation, NASA concluded, “It was most likely that the fire began in the lower forward portion of the left equipment bay, to the left of the command pilot, and considerably below the level of his couch. … The first stage, with its associated rapid temperature rise and increase in cabin pressure, terminated 15 seconds after the verbal report of fire. At this time, 23:31:19 GMT, the command module cabin ruptured. During this first

stage, flames moved rapidly from the point of ignition, traveling along debris traps installed in the command module to prevent items from dropping into equipment areas during tests or flight. … The fire was not intense until about 23:31:12 GMT. … The original flames rose vertically and then spread out across the cabin ceiling. The debris traps provided not only combustible material and a path for the spread of the flames, but also firebrands of burning molten nylon. … By 23:31:12 GMT, the fire had broken from its point of origin. A wall of flames extended along the left wall of the module, preventing the command pilot, occupying the left couch, from reaching the valve that would vent the command module to the outside atmosphere."

The second and third stages were worse, but also shorter. According to NASA's findings, "Rupture of the command module marked the beginning of the brief second stage of the fire. This stage was characterized by the period of greatest conflagration due to the forced convection that resulted from the outrush of gases through the rupture in the pressure vessel. The swirling flow scattered firebrands throughout the crew compartment, spreading fire. This stage of the fire ended at approximately 23:31:25 GMT. This third stage was characterized by rapid production of high concentrations of carbon monoxide. Following the loss of pressure in the command module and with fire now throughout the crew compartment, the remaining atmosphere quickly became deficient in oxygen so that it could not support continued combustion. Unlike the earlier stages where the flame was relatively smokeless, heavy smoke now formed and large amounts of soot were deposited on most spacecraft interior surfaces as they cooled. The third stage of the fire could not have lasted more than a few seconds because of the rapid depletion of oxygen. It was estimated that the command module atmosphere was lethal by 23:31:30 GMT, five seconds after the start of the third stage."

The doctors also weighed in on why the men died so quickly, including what problems within the module itself contributed to their deaths. They maintained "that the fire originated in the cabin rather than in the suit circuit." They also agreed that the fire "was most intense on the Command Pilot's side of the spacecraft," and the suits "were not capable of providing crew protection in a fire of this intensity." Finally, they noted, "Rescue personnel were inadequately equipped for a fire-type rescue."

A picture of the Apollo 1 medallion, one of which was carried on Apollo 9

Naturally, Americans of all stripes wanted to know what happened with Apollo 1 and why. For one thing, sabotage was considered a real possibility by many; the Space Race with the Russians was a very heated affair, so it seemed perfectly plausible that they might do something to stop American progress. There were also allegations that NASA officials were incompetent, and that someone somewhere failed to do their job properly. Finally, there was the matter of financing, as NASA was coming under increased scrutiny to actually land a man on the moon. Many understandably wondered how the space agency could get an astronaut to the Moon and back if it couldn't even protect its astronauts on the ground here.

Of course, NASA not only had the responsibility to answer the questions but plenty of motive to do so in a satisfactory manner. Within minutes of the accident being reported, NASA sent in security personnel to secure Launch Complex 34, where the fire had taken place, but once the men were determined to be dead, there was no more hurry and investigators took their time in documenting the scene and everything in it. According to NASA's final report, "Small groups of NASA and North American Aviation management, Apollo 204 Review Board members, representatives, and consultants inspected the exterior of Spacecraft 012…A detailed inspection

of the spacecraft interior was then performed, followed by the preparation and approval by the Board of a command module disassembly plan." Following this plan, the entire module was packed up and shipped to a hanger at the Kennedy Space Center on February 1. Over the next several weeks, it was dismantled, piece by piece, with every item and spacecraft components being carefully photographed and studied as it was being removed. As NASA later reported, "All interfaces such as electrical connectors, tubing joints, physical mounting of components, etc. were closely inspected and photographed immediately prior to, during, and after disassembly. Each item removed from the command module was appropriately tagged, sealed in clean plastic containers, and transported under the required security to bonded storage."

By March 27, 1967, the module had been completely disassembled and thousands of its pieces had been photographed and catalogued. Throughout the process, the priority remained the same: determine what caused the fire. According to the board's Final Report, "Throughout the disassembly operation, experts meticulously studied the exposed portions of the Command Module. The relative consumption of combustibles and sooting patterns were studied for clues as to the site of the ignition source. All structural elements, covers and panels were examined for evidence of association with the ignition. Component systems and parts were studied inch by inch with magnifying glasses and frequently parts were taken into the laboratory for microscopic or metallurgical analysis. Wire bundles were given particular attention and after separation, the individual wires were examined under 7-power magnification for sites of possible arcing. All components that showed evidence of abnormal fire effects were examined internally and many were tested for functionality. Many components showed burning of internal insulation or plotting material but in all cases they were exonerated on the basis of direction of flame travel or on the basis that there could be no communication with combustibles outside the component. Particularly suspect components were disassembled for detailed examination and analysis. All of the data developed by these visual and laboratory examinations were coordinated in making the final analysis as to probable ignition sources."

Meanwhile, another team was busy analyzing the data they had collected,

beginning by creating a timeline based on “significant data that were obtained just prior to the report of the fire by the astronaut crew. These time lines cover the period of one minute before the fire report until all data signals were lost. The data shown includes signals from the gas chromatograph channel, the voltage of the AC Bus 2, the C-band beacon, the VHF telemetry carrier, the flow of oxygen into the suit loop, various indicators of spacecraft motion, the biomedical data from the Senior Pilot, and audio signals (voice and noise) received on the S-band communication link. An analysis of each item and a summary of their correlation follows.”

After extensive and meticulous study, the Board asserted that “30 and 45 seconds prior to the report of fire, both the Command Pilot and Senior Pilot were active. The nature and level of the activity remain unknown. Except for the transients in data measurements that occurred approximately 9 seconds prior to the report of the fire, there are no other identified relevant events that preceded the fire. It should be noted that these data transients and subsequent activity of the crew may as easily be associated with the result of the fire as with the cause. The increase in oxygen flow to the suit loop prior to and immediately following the report of the fire and its effect on the pressure distribution within the suit loop is the result of normal demand regulator response to oxygen leaking from the circuit to the cabin. This is further compounded by the response of the regulator to the rise in cabin pressure.”

The report went on to draw a number of conclusions, including that the fire was most likely caused by “an electrical arc in the sector between -Y and +Z spacecraft axes. The exact location…is [likely] near the floor in the lower forward section of the left-hand equipment bay where Environmental Control System (ECS) instrumentation power wiring leads into the area between the Environmental Control Unit (ECU) and the oxygen panel. No evidence was discovered that suggested sabotage.” Furthermore, the investigators described the test conditions as “extremely hazardous” and admitted that the “rapid spread of fire caused an increase in pressure and temperature which resulted in rupture of the Command Module and creation of a toxic atmosphere. Death of the crew was from asphyxia due to inhalation of toxic gases due to fire. A contributory cause of death was thermal burns…unconsciousness occurred rapidly and that death followed soon thereafter.”

Perhaps the most disturbing finding was that the men likely never had a chance of survival since they were "never capable of effecting emergency egress because of the pressurization before rupture and their loss of consciousness soon after rupture." To avoid a similar occurrence, the committee recommended "the time required for egress of the crew be reduced and the operations necessary for egress be simplified."

The committee also asserted, "Adequate safety precautions were neither established nor observed for this test." They based this conclusion on the following list of problems:

- "Those organizations responsible for the planning, conduct and safety of this test failed to identify it as being hazardous. Contingency preparations to permit escape or rescue of the crew from an internal Command Module fire were not made."
- "No procedures for this type of emergency had been established either for the crew or for the spacecraft pad work team."
- "The emergency equipment located in the White Room and on the spacecraft work levels was not designed for the smoke condition resulting from a fire of this nature."
- "Emergency fire, rescue and medical teams were not in attendance."
- "Both the spacecraft work levels and the umbilical tower access arm contain features such as steps, sliding doors and sharp turns in the egress paths which hinder emergency operations."

In response, the committee made a list of recommendations:

- "Management continually monitor the safety of all test operations and assure the adequacy of emergency procedures"
- "All emergency equipment (breathing apparatus, protective clothing, deluge systems, access arm, etc.) be reviewed for adequacy"
- "Personnel training and practice for emergency procedures [should] be given on a regular basis and reviewed prior to the

conduct of a hazardous operation and that service structures and umbilical towers [should] be modified to facilitate emergency operations."

The committee also found the communication system "unsatisfactory" and suggested it be improved. They further called for studies to be done to see if the atmosphere within the module could be reduced from pure oxygen to some breathable mixture that was less flammable.

In all, the Review Board found a number of what they termed "deficiencies" in the "Command Module['s] design, workmanship and quality control." These included the following:

- "Components of the Environmental Control System installed in Command Module 012 had a history of many removals and of technical difficulties including regulator failures, line failures and Environmental Control Unit failures. The design and installation features of the Environmental Control Unit make removal or repair difficult."
- "Coolant leakage at solder joints has been a chronic problem."
- "The coolant is both corrosive and combustible."
- "Deficiencies in design, manufacture, installation, rework and quality control existed in the electrical wiring."
- "No vibration test was made of a complete flight-configured spacecraft."
- "Spacecraft design and operating procedures currently require the disconnecting of electrical connections while powered."
- "No design features for fire protection were incorporated."

In response to these and other findings, the Review Board made the following suggestions:

- "An in-depth review of all elements, components and assemblies of the Environmental Control System be conducted to assure its functional and structural integrity and to minimize its

contribution to fire risk."

- "Present design of soldered joints in plumbing be modified to increase integrity or the joints be replaced with a more structurally reliable configuration."
- "Deleterious effects of coolant leakage and spillage be eliminated."
- "Review of specifications be conducted, 3-dimensional jigs be used in manufacture of wire bundles and rigid inspection at all stages of wiring design, manufacture and installation be enforced."
- "Vibration tests be conducted of a flight-configured spacecraft."
- "The necessity for electrical connections or disconnections with power on within the crew compartment be eliminated."
- "Investigation be made of the most effective means of controlling and extinguishing a spacecraft fire. Auxiliary breathing oxygen and crew protection from smoke and toxic fumes be provided."

All of the analyses made clear that NASA needed to fix the command module, not only because of potential problems on the ground but also ones that might take place in space. As the report pointed out, "Once the Command Module has left the earth's environment the occupants are totally dependent upon it for their safety. It follows that protection from fire as a hazard involves much more than a quick egress. The latter has merit only during test periods on earth when the Command Module is being readied for its mission and not during the mission itself. The risk of fire must be faced; however, that risk is only one factor pertaining to the reliability of the Command Module that must receive adequate consideration. Design features and operating procedures that are intended to reduce the fire risk must not introduce other serious risks to mission success and safety."

Webb and other NASA officials testifying before Congress

In addition to NASA's internal investigations, the United States Senate also held hearings to determine what went wrong and what should be changed in the future. With typical political tact, the Senate committee reported, "The committee recommends that NASA continue to move the Apollo program forward to achieve its goal. … The Apollo 204 accident, however, may well cause the date for an American landing on the moon to be accomplished early in the next decade outside the schedule set in 1961. That would be regrettable. When set in 1961, it was a goal set for achievement and it was technically feasible. While this goal had attracted a great deal of attention in terms of national prestige, as pacesetter for the program and as rallying point for the people on the program, its true significance is seldom mentioned. The target date was and still is essential to efficient management of the program. It is essential to the planning process and to maintain a vigorous and

competent organization. Any program and particularly the largest and most complex research and development program ever undertaken by man—the Apollo program—must have scheduled goals. The schedule is an essential and significant management tool—without it the program would require more and more time and more and more money."

The men on the committee knew they had to walk a fine line regarding what they wrote because their findings would likely be read with more interest than those of the average Senate committee. They also had to strike a balance between respecting the lives lost and casting blame, especially on one of the nation's most popular programs. "Safety must be considered of paramount importance in the manned space flight program even at the expense of target dates. The earnest declaration that "safety is our prime consideration" must be transfused into watchfulness so that people do not again stumble into the pitfall of complacency. NASA's creation of a Flight Safety Office with broadened capabilities and better lines of communication is a step in that direction. The Congress, in the National Aeronautics and Space Administration's fiscal year 1968 authorization act, directed the Administrator to appoint an Aerospace Safety Advisory Panel to review NASA's operational plans and advise the Administrator with respect to the hazards of proposed or existing facilities, proposed operations, and on the adequacy of [proposed or existing safety standards. The committee urges NASA to continue its post-accident efforts to achieve a high degree of safety in all of its operations and we recommend that NASA utilize the above-mentioned organizations to achieve the primacy in safety desired."

Still, there was one more piece that had to be dealt with: the Senate's own right and responsibility to oversee any government institution. Therefore, the committee concluded its remarks with a fair but firm warning: "Finally, the committee urges that the National Aeronautics and Space Administration keep the appropriate congressional committees informed on significant problems arising in its programs. During the hearings it was found that late in 1965 NASA found serious problems with the contractor's management of the contracts for the Apollo command and service module spacecraft and S-II stage—the second stage of the Saturn V vehicle. Notwithstanding that in NASA's judgment the contractor later made significant progress in overcoming the problems, the committee believes it should have been

informed of the situation. The committee does not object to the position of the Administrator of NASA, that all details of Government/contractor relationships should not be put in the public domain. However, that position in no way can be used as an argument for not brining this or other serious situations to the attention of the committee."

Eventually, NASA was able to use what it learned from the disaster to make effective changes to the designs of the Apollo spacecraft. As one report later admitted, "As a result of the investigation, major modifications in design, materials, and procedures were implemented. The two-piece hatch was replaced by a single quick-operating, outward opening crew hatch made of aluminum and fiberglass. The new hatch could be opened from inside in seven seconds and by a pad safety crew in 10 seconds. Ease of opening was enhanced by a gas-powered counterbalance mechanism. The second major modification was the change in the launch pad spacecraft cabin atmosphere for pre-launch testing from 100 percent oxygen to a mixture of 60 percent oxygen and 40 percent nitrogen to reduce support of any combustion. The crew suit loops still carried 100 percent oxygen. After launch, the 60/40 mix was gradually replaced with pure oxygen until cabin atmosphere reached 100 percent oxygen at 5 pounds per square inch. This 'enriched air' mix was selected after extensive flammability tests in various percentages of oxygen at varying pressures."

There were a number of other less dramatic but important changes made to the module, including "substituting stainless steel for aluminum in high-pressure oxygen tubing, armor plated water-glycol liquid line solder joints, protective covers over wiring bundles, stowage boxes built of aluminum, replacement of materials to minimize flammability, installation of fireproof storage containers for flammable materials, mechanical fasteners substituted for gripper cloth patches, flameproof coating on wire connections, replacement of plastic switches with metal ones, installation of an emergency oxygen system to isolate the crew from toxic fumes, and the inclusion of a portable fire extinguisher and fire-isolating panels in the cabin."

NASA also used what it learned from the Apollo 1 fire to make improvements to Launch Complex 34. Among those were "structural changes to the White Room for the new quick-opening spacecraft hatch,

improved firefighting equipment, emergency egress routes, emergency access to the spacecraft, purging of all electrical equipment in the White Room with nitrogen, installation of a hand-held water hose and a large exhaust fan in the White Room to draw smoke and fumes out, fire-resistant paint, relocation of certain structural members to provide easier access to the spacecraft and faster egress, addition of a water spray system to cool the launch escape system (the solid propellants could be ignited by extreme heat), and the installation of additional water spray systems along the egress route from the spacecraft to ground level."

While these and other changes made the space program safer, no one would ever describe it as completely safe, any more than one might describe air travel or driving a car as completely safe. It was only possible for those in charge to minimize the risks while maximizing the rewards, and of course, the rewards were ultimately great. On July 20, 1969, two and a half years after the Apollo 1 tragedy, NASA scored its greatest success to date when Neil Armstrong and Buzz Aldrin finally planted their boots on the Moon as members of Apollo 11. One of the items Armstrong carried that day was a diamond-studded pin intended to fly with Apollo 1 and subsequently given to the agency by the three astronauts' widows.

MICHAEL J ADAMS
VIRGIL "GUS" GRISSOM
EDWARD H WHITE II
ROGER B CHAFFEE

IN MEMORY
OF
THOSE WHO MADE THE ULTIMATE SACRIFICE
SO OTHERS COULD REACH FOR THE STARS
AD ASTRA PER ASPERA
(A ROUGH ROAD LEADS TO THE STARS)
GOD SPEED TO THE CREW
OF
APOLLO 1

LAUNCH COMPLEX 34
Friday, 27 January 1967
1831 Hours
Dedicated to the living memory of the crew of the Apollo 1:
U.S.A.F. Lt. Colonel Virgil I. Grissom
U.S.A.F. Lt. Colonel Edward H. White, II
U.S.N. Lt. Commander Roger B. Chaffee
They gave their lives in service to their country in the ongoing exploration of humankind's final frontier. Remember them not for how they died but for those ideals for which they lived.

Pictures of memorials to the Apollo 1 crew at Cape Canaveral

A modern picture of the launch pedestal used by Apollo 1

The Soyuz Program

Sergei Korolev, the person responsible for so many achievements throughout the 1950s and 1960s, died after a failed surgery in 1966. Korolev had received a thorough examination at the Kremlin's medical center, where he was declared in very good health. In fact, William E. Burrows recounts the story of Korolev being told he had another 20 years to expect of a long and healthy life. A slightly bleeding polyp in Korolev's colon, however, was scheduled to be removed, and during what should have been routine surgery, Korolev began bleeding uncontrollably. Moreover, an additional large tumor was found in his abdomen. As a result of the bleeding and strain on Korolev's heart, he died on the operating table.[140] Brian Harvey claims that with Korolev's death, the Soviet space program was severely undermined, crediting Korolev with the ability and drive to carry out so many Soviet space achievements along with his political cohort, Khrushchev.[141]

The death of Korolev and his vision, as well as the tragedy of America's Apollo I fire and the death of three American astronauts on January 27, 1967, shook the space community and later elicited the following remarks from the head of cosmonaut training, General Kamanin: "We must be fully convinced, however, that the fight will be a success. The flights we are preparing will be more complicated than the previous ones, and thus preparation for them will have to be appropriately longer. We do not intend to speed up our programme. Excessive haste leads to fatal accidents, as in the case of the tragic deaths of three American astronauts last January."

The caution the Soviets had promised was in question when they launched Soyuz, the Soviet's first manned mission since Voskhod 2.[142] Soyuz I had was supposed to be the fulfillment of a long-awaited multiple-manned mission, but when it launched in April of 1967, only one cosmonaut, Vladimir Komarov, was on board.[143] The Soviets had been unusually reticent about the purposes of this flight, but many suspected that Soyuz would rendezvous with another craft to be launched in the day following and complete a docking and exchange mission.[144] In fact, the name Soyuz means union in Russian.[145]

Komarov

What happened instead would be a matter of controversy for years to come. After its initial orbit, Soyuz developed problems; the craft had been designed with two solar panels which would allow for Soyuz to draw power from the sun rather than a battery, but only one of the panels opened, which meant that

the systems were operating with only half of the power intended.[146] An attempt to use other systems to generate enough electricity to open the second panel failed, and the Soyuz developed communication problems as well. Between the 7th and 13th orbits, Soyuz would have no communication with ground control and Komarov was directed to "try to get some sleep."[147] When contact was re-established at the 17th orbit, Soyuz was "out of control," according to the Soviet flight control director. "The spacecraft is going into tumbles that the pilot has difficulty controlling. We must face the truth. He might not survive re-entry."[148]

At that point, it was decided that the second launch would be canceled and the rest of the mission aborted, and though Komarov did an admirable job of bringing Soyuz back under control for re-entry, the extreme speed with which it entered the atmosphere caused the two chutes that Komarov deployed to become twisted and useless in slowing the craft down. Soyuz impacted the Earth at 400 miles per hour, and Komarov's body was recovered in the ashes. [149]

The Soyuz mission remains a point of controversy. Many say that Komarov went into space knowing that the Soyuz was unready and agreed to the mission only to save his backup cosmonaut and friend, Yuri Gagarin, who had discovered over 200 structural problems with the craft and recommended that the mission be postponed.[150] According to testimony of those listening to transmissions in nearby Turkey, Komarov died "cursing the people who had put him inside a botched spaceship."[151] While that is considered by many to be an apocryphal story, there's no doubt Komarov must've had those kinds of thoughts running through his mind as he met his end.

The Soviets continued the development of Soyuz, making changes that allowed them to launch Soyuz 2 (unmanned) in October of 1968 and Soyuz 3, a manned flight, only a day later.[152]

When it started becoming clear to the Soviets that they might lose the race for a manned mission to the moon, Soviet political leaders encouraged designers and engineers to compete with one another for alternative firsts. Failures were to be kept as quiet as possible, and successes broadcast as great Soviet victories. The Zond and Venera missions aimed for landings on Mars and Venus respectively, and while more than 20 of these attempts failed, the

Soviets were eventually successful in at least crash landing a craft onto both planets.[153]

There can be no doubt that the Soviet space program had begun to decline in its accomplishments in the late ‘60s as funding mechanisms slowed, the United States successfully landed a man on the moon, and program failures brought the height of former Soviet space glory to an end. Authors James T. Andrews and Asif A. Siddiqi offer dual explanations for the communist party’s interest in a space program. Though the first is simply the Marxist desire for power and reshaping, another explanation “derived from the Bolshevik’s own vision to remake Russia into a modern state, one that would compare and compete with the leading capitalist nations in forging a new path to the future.”[154]

Whatever the ultimate goal, the Soviet space program enhanced the reputation of the Soviet system in the eyes of much of the world, kept pressure on the United States, and provided millions of Soviet citizens a sense of pride and accomplishment. Dora and Bizony note the rarity of individual glory in Soviet life and cultural history, and point out how the legacy of the space program breaks that rule, with men like Gagarin recalled “with genuine affection a peasant boy with a winning smile” and manned space flight itself being a win against the Americans, who arrived late in popular eyes.[155]

Russia’s celebration of Gagarin’s accomplishments included the 1975 Gagarin march that commemorated Vostock I’s accomplishment. The song’s lyrics were spliced with recordings of Gagarin’s transmissions to earth:

“This is Moscow

This is Moscow calling

On the 12th of April, the Soviet Union orbited a spaceship around the Earth with a man on board

The astronaut is a Soviet citizen: Major Gagarin, Yuri Alekseyevich

The World's first cosmonaut

The first to open the door into the unknown

The first to step over the threshold of our homeland

The whole planet knew him and loved him

Gagarin...

Was it hazardous? Yes, it was

The first strides into the unknown were about to be made

The hero who blazed the trail for the stars

Every one of us was with Yuri Gagarin as he orbited the Earth
190 miles above us.

Astronaut to Earth: I can see forests, rivers, [?] all around

Everything's so beautiful, it's wonderful, it’s wonderful...

The whole planet knew him and loved him.”

A Soviet propaganda poster of the early ‘60s features a red hand, outstretched to the sky and sending off a red rocket marked “CCCP.” The proud poster reminded each citizen who watched the skies in hope of the next event, “Soviet man—be proud, you opened the road to stars from Earth!" "Glory to the conquerors of the universe!"[156]

Apollo Missions Before Apollo 11

Already by late 1961, NASA had begun to mention the “Lunar Excursion Module” (LEM) as the agency’s choice to land men on the Moon. Events worked quickly to decide once and for all where the LEM would rendezvous with the other spacecraft, and when NASA confirmed the ascendance of LOR, the development of the LEM commenced in full. “Considerable analytical and experimental work was underway on engineering problems associated with landing the LEM on the Moon. Landing loads and stability were studied by dropping dynamically scaled models on simulated lunar soil and by computer runs which utilized mathematical models of both the LEM and the lunar surface. At the same time an effort was underway to deduce in engineering terms the surface characteristics and soil mechanics of the lunar surface, Only the sparse photographic information from Ranger [space probe] was available to the engineers, yet later data from Surveyor and Orbiter [space probes] led to no significant change in the LEM design.”[157]

Apollo proceeded on pace, and what some would call a rushed pace; to keep pace with Gemini and maintain the ambitious schedule of goals, the Command Service Module (CSM) and LEM were sped along. The program meant for its maiden flight to carry three astronauts, quite a risk given the new technologies under use. But as each successive stage of the Saturn rocket shot into space, each uncrewed launch of mockups and different capsule mockups only put more pressure on the deadline to launch a manned Apollo flight. The authors of *The Apollo Spacecraft* explained, “While the Mercury and Gemini spacecraft were being developed and operated, the three-man Apollo program had grown in magnitude and complexity and included a command module, a service module, a lunar module, and a giant Saturn V rocket. The spacecraft and launch vehicle towered 110 meters above the launching pad, and weighed some 3 million kilograms. With the Apollo program, the missions and flight plans had become much more ambitious, the hardware had become more refined, the software had become more sophisticated, and ground support equipment also grew in proportion.”[158]

If anything, too much success came too quickly. While Soviet space advances put pressure on NASA to speed up Apollo, the program’s inflexible schedule created an inevitable moment of truth. The capsule that showed up

at the Kennedy Space Center launch pad possessed more than 19 pounds of combustible materials, and in the wake of the Apollo 1 disaster, the struggle to build Apollo obviously took its toll on the engineers and mechanics. In fact, it ended with the abandonment of Launching pad 34 and a plaque: “Ad Astra per aspera” (“A rough path leads to the stars”.

NASA went back to work on Apollo, knowing the Soviets would seize on the opportunity. Apollo 2 and 3 were cancelled, with their objectives segmented into other missions along with the Saturn V rocket.

Apollo 4, 5 and 6 were launched without crews, and when this was judged satisfactory, Apollo had its first flight crews. NASA could replace rockets, but it had a harder time to replace well-trained astronauts, the best pilots America possessed, even if they understood the “rough path” to the “stars” and heeded the words of Grissom: “If we die, we want people to accept it. We hope that is anything happens to us it will not delay the program. This conquest of space is worth the risk of life.”[159]

Still, the space program could ill afford to lose any more astronauts during training; and this is exactly what nearly occurred to Armstrong in his preparations for piloting the LEM. As early as 1960, NASA had planned for the proper simulator to train astronauts to land on the Moon, and after many ambitious proposals, NASA settled on the most complex of them all, the Lunar Landing Research Vehicle, a truss of lightweight aluminum mounted to a jet engine. There was a special mode called the lunar simulation mode that the pilot would engage, and the mode commanded the jet engine to support only five-sixths of the LLRV’s weight. Along with this, it had a cockpit that rotated freely of the engine so the effect of lunar gravity could then be achieved. A pilot would sit in an open air cockpit, ascend like a plane, and then adjust the jets to behave as they would in lunar gravity. The pilot would then attempt to settle the craft down onto the ground, using the same controls of the LEM.

By 1968, Neil Armstrong and Pete Conrad were in line to command the first lunar missions. Their training took place at Dryden; and Armstrong and Conrad had made 20 and 13 flights respectively. For Armstrong’s 21st test flight, the switch into lunar mode went off perfectly until the LLRV went sideways. Armstrong now flew the simulator on his side, and he attempted to

right the trainer, but it failed to respond to his controls. The LLRV began to lose altitude rapidly, and Armstrong was left with little recourse but to eject. He did, floating away on a parachute just 200 feet off the ground as the LLRV crashed nearby and erupted into a fireball. Armstrong's only remark to his fellow astronauts was, "I had to bail out of the darn thing."[160] Five of the seven LLRVs ultimately crashed or blew up in flight, but no pilots died.

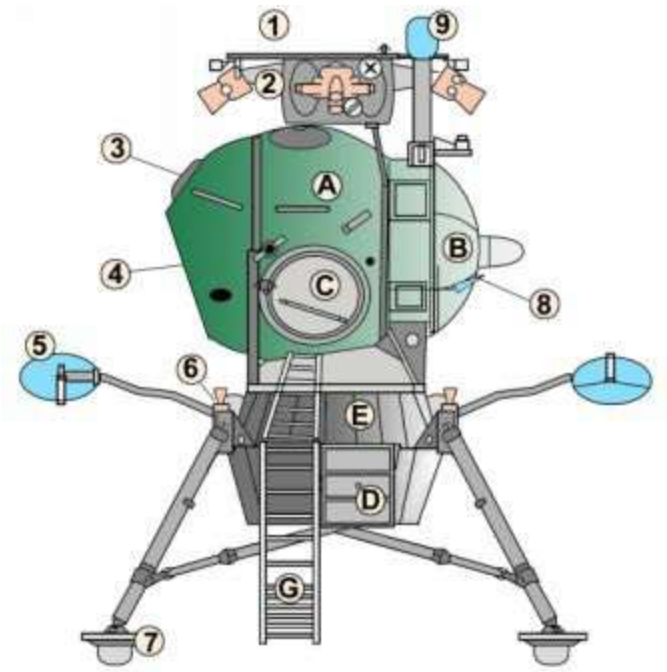
An LLRV

What Armstrong took from that experience is worth mentioning because his skills, more than anything, justified his command of Apollo 11, and

ultimately, his role as the first man to step on the Moon. Other factors have been considered for his choice as well: the military chain of command perspective, which favored Armstrong due to NASA's "naval genetic code"; an engineering perspective, with the LEM's design giving precedence to the command pilot who was closer to the door; and lastly, and the personality perspective, which most astronauts identified as Aldrin's "lack of finesse". But above all, Armstrong served as the logical choice due to the abilities he demonstrated as a pilot.[161] During test flights, he had demonstrated the best qualities of an astronaut-engineer, one who could successfully lead a mission of the Apollo spacecraft and personally set foot on the lunar surface. Apollo was the epitome of technology and training, and Armstrong had all the characteristics of an individual best suited to command a mission from the Earth to the Moon, and most importantly, make the first manned landing.

The ambitiousness of the Saturn-Apollo schedule had cost it the lives of three astronauts, but with the resumption of the missions, NASA seemed back on track. However, the agency and the manned lunar program needed a significant morale boost that ambitions alone could not provide. While "Apollo Applications" provided a blueprint for the future -- lunar bases from used Saturn upper stages, LEM "trucks," and a Venus flyby mission -- the mid-1960s saw the U.S. and the Soviets in nearly the same position. Both seemed ready to launch missions to the Moon.

The U.S.S.R. had achieved a bunch of successes that gave America's space rival the ability to keep pace with the U.S. The soft-landing of the moon probe Luna 9 gave NASA great worry, as too did the rendezvous docking between Soyuz 1 and 2. With that, the Soviets appeared to have two important parts of a mission covered: lunar landing and orbital docking. Soon came the launching of Zond, a further modification of the Soyuz and a worthy rival to Apollo. The Zond was a spacecraft that, while in automated form, could theoretically make the trip to the Moon. The Soviets also stepped up their program with the launch of the LK Lunar Lander, and its impressive orbital maneuvers were later bookended by the other Soviet improvements to Soyuz, with another docking between missions 4 and 5. The Soviets had their moon craft and the ability to land. All they needed was a powerful enough booster, and one that was reliable.[162]



The Soviet design

The success of the Saturn-Apollo complex can be attributed to the original vision of NASA and the first professionals who guided the agency and its plans for spaceflight. More was needed than a reliable rocket; any lunar mission required the best computer and software to navigate and operate the spacecraft. The civilian contribution to U.S. spaceflight, despite its military leanings, began partly from a utopian vision for any type of "Space Race" between nations. Superpowers could compete with one another. As aerospace technologist Paul Lowman says of the success of Apollo, "It seems safe to suggest that his demonstration is a real contribution to prevention of a global thermonuclear war no potential aggressor could plan a surprise attack on the United States without taking into account the military strength implied by it."[163] In a sense, the Space Race kept the Cold War from heating up.

While the professionals who built, tested and launched the Saturn-Apollo complex of ships bore out the tough work of the engineering and mechanical corps of America, their dedication reflected the passion of one of manned spacecraft's founders: Wernher Von Braun, the expatriate rocket scientist from the defeated Third Reich. His military origin notwithstanding, von

Braun was repeatedly stymied by U.S. military leaders, even though he did actively court them by touting the benefits of manned spaceflight. Rejected, he offered his vision to the American public, who eagerly read his vision in *Collier's* magazine as early as 1952. With visions of winged rockets and space stations in the public's head, von Braun found it easy to outline a "new" Manhattan Project, one that NASA would eventually adopt, and a blueprint that NASA would use to court the public sector. No other place demonstrated this early collaboration of civilian and military rocket scientists than Huntsville, Alabama, known also as "Rocket City." Here the first non-military rocket professionals worked on the first rockets to carry Americans into outer space, and a government-funded and civilian-led space program began.[164]

NASA's use of civilian contractors hired by the government created an initial problem that was never properly fixed by the time of Apollo. The agency never had enough experience, which meant that any astronauts who strapped themselves into a capsule on top of a Saturn rocket were in the hands of professionals who were forced to invent spacecraft systems. Despite the gap in experience, the civilian engineers responded with specific knowledge in unproven fields, most notably their invention of escape systems for astronauts in the event of a launch pad accident.[165] After Apollo 1, Nelson explained, "Pad catastrophe was such a grave responsibility, in fact, that NASA had engineered a number of methods to rescue its crews. The key system was a three rocket apparatus -- the launch escape tower -- attached to *Columbia's* [Apollo 11's SC] nose cone, ready to fire, pull the men from their booster, deploy the chutes, and drift into an Atlantic splashdown.[166]

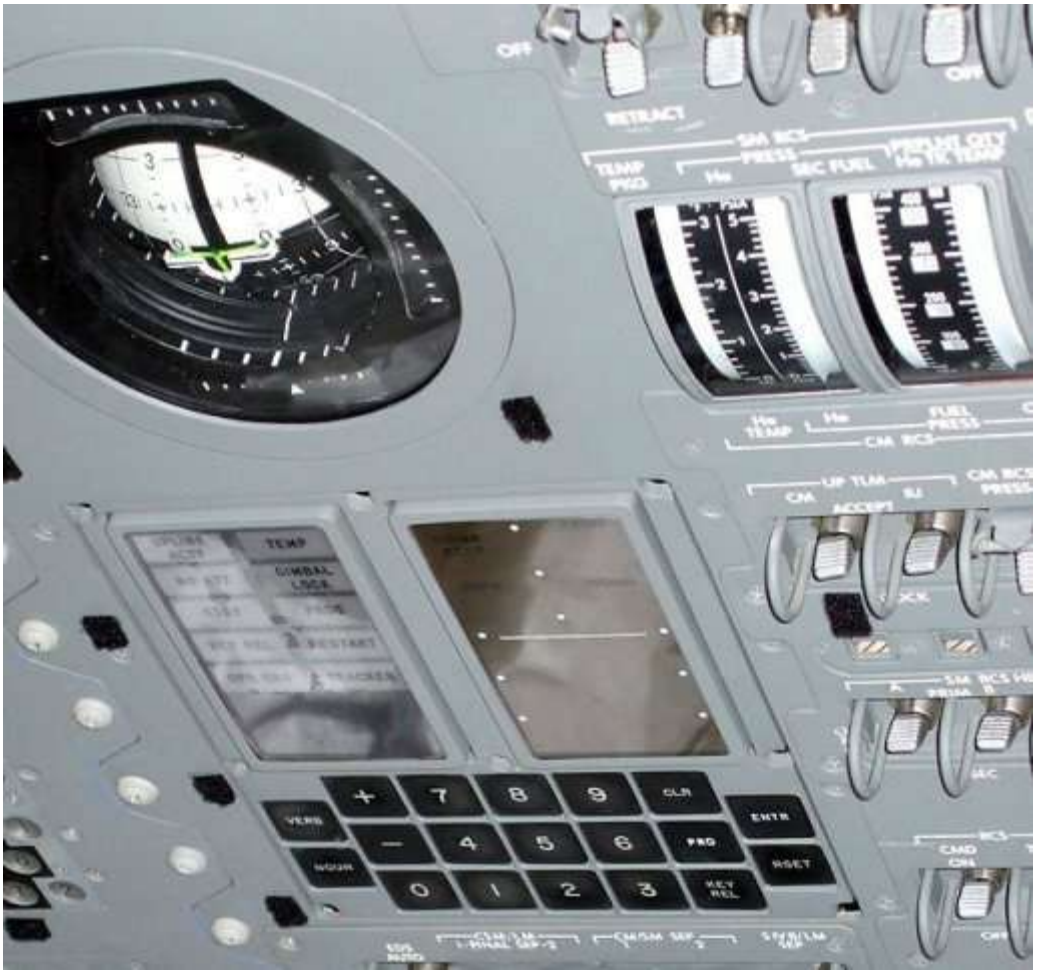
While the engineers and technicians found themselves in tight situations to design launch systems, the Apollo astronauts themselves found themselves increasingly stressed by the pervasive doubts about the quality and duration of their training. "Apollo 11's Neil Armstrong, Buzz Aldrin, and Michael Collins did not themselves feel adequately trained. But they were afraid to admit this to [Deke] Slayton [flight crew operations director]. 'Neil used to come home with his face drawn white, and I was worried about him,' Armstrong's wife, Jan, remembered. 'I was worried about all of them. The worst period was in early June. Their morale was down. They were worried about whether there was time enough for them to learn the things they had to

learn, to do the things they had to do, if this mission was to work.'[167]

At the same time, NASA had to deal with requesting funding from a Congress that remembered the early rocket disasters and responded to the space agency's request for money with a modest budget to fund the Saturn rocket. The perception of the civilians who worked on Saturn and Apollo was that their own government prevented them from the creation of an adequate program that could challenge the Soviets and beat them to the Moon.[168] Ultimately, computers made a significant difference in the Apollo Program's success by boosting American confidence in the ability of astronauts to pilot a craft to orbit, land, and return from the Moon. The *Columbia* command module possessed two 17.5-pound Raytheon computers, and the lunar module *Eagle* had one computer. The memory of each one was 36K. While far less impressive than early 21st century cell phones, each computer was much more spectacular in its function, and especially its importance. Nothing was more vital to a mission to the Moon than the computer system with the responsibility to chart the course and deliver the spacecraft to the intended target. This was Guidance and Navigation, which was tasked with guiding the Apollo spacecraft across 250,000 miles of space, orbit around the Moon, land at a targeted location on the surface, guide the *Eagle* from the surface back to the *Columbia* in orbit, guide the *Columbia* towards a space in the Earth's atmosphere that would "capture" the capsule; and land the *Columbia* near a recovery ship in the Pacific Ocean. As Nelson put it in *Rocket Men*, "G&N consisted of a miniature computer with an incredible amount of information in its memory; an array of gyroscopes and accelerometers called the inertial-measurement unit; and a space sextant to enable the navigator to make star sightings. Together they determined precisely the spacecraft location between Earth and Moon, and how best to burn the engines to correct the ship's course or to land at the right spot on the Moon with a minimum expenditure of fuel."[169]

Computers were, in many regards, the key to Apollo 11 solving the key problem of the mission: a circular lunar orbit needed for insertion. How well the astronauts worked with the G&N would leave them with a decision on the far side of the Moon. Either they could use the systems to correct their path to enter orbit, or they would have to burn engines to abort the mission and return home.[170] At least in that scenario, the lives of the astronauts would be

saved by the computers, while the tough decision to land or not would be avoided by the cool calculation of a computer.



The display and keyboard of the Apollo Guidance Computer on the *Columbia*

The helpful advice of a computer might not always be heeded though. During computer simulations of a mission, Armstrong and ground control repeatedly had heated discussions over the possibility of abort, especially if Earth-based radar perceived a threat to landing. In this case, Armstrong refused to defer to computers and rely on his own intuition, which worried NASA mission controllers. They were fearful that a pilot like Armstrong would decide to make a decision that computer simulations said he could not survive, and further ignore the advice of the computers in Houston.[171] NASA

was so worried about the possibilities that President Nixon prepared a speech for the event of Apollo 11's crash or inability to leave the Moon.[172] Nixon's statement read:

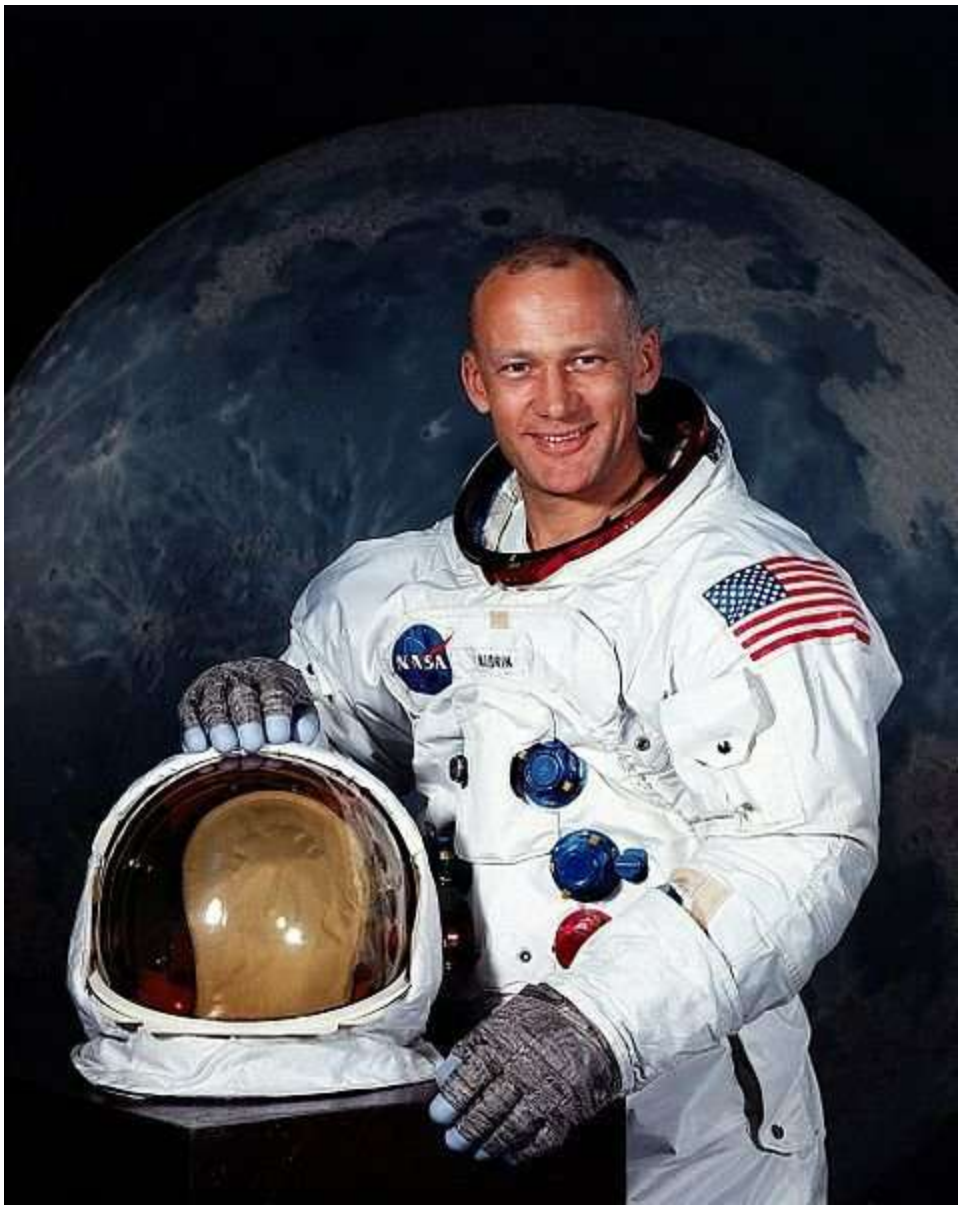
> "Fate has ordained that the men who went to the moon to explore in peace will stay on the moon to rest in peace. These brave men, Neil Armstrong and Edwin Aldrin, know that there is no hope for their recovery. But they also know that there is hope for mankind in their sacrifice. These two men are laying down their lives in mankind's most noble goal: the search for truth and understanding. They will be mourned by their families and friends; they will be mourned by their nation; they will be mourned by the people of the world; they will be mourned by a Mother Earth that dared send two of her sons into the unknown. In their exploration, they stirred the people of the world to feel as one; in their sacrifice, they bind more tightly the brotherhood of man. In ancient days, men looked at stars and saw their heroes in the constellations. In modern times, we do much the same, but our heroes are epic men of flesh and blood. Others will follow and surely find their way home. Man's search will not be denied. But these men were the first, and they will remain the foremost in our hearts. For every human being who looks up at the moon in the nights to come will know that there is some corner of another world that is forever mankind."[173]

Assembling the crews for Apollo together, and especially the men who would land on the Moon, required combining talents and individuals who could fulfill every complex task along the way. The U.S. space program had begun with military test pilots who became astronauts, and training the astronauts for a lunar mission continued the same grueling tasks.[174] Nelson wrote in *Rocket Men,* "Overtraining' barely described Apollo 11's punishing workload. besides all the astronauts spending fourteen-hour days in the Houston simulators learning everything that could possibly go wrong with machines and their ground controllers, Collins also had a docking simulator at Langley, Virginia, to fly; space suits in Delaware to test; and 10 gs of centrifuge to overcome...Each would-be astronaut was monitored by doctors who tested his response to the stress of ahd decelerations and up to 15 gs of

force, pressure that flattened eyeballs and burst capillaries."[175]

Other factors that Apollo astronauts shared with their predecessors were educational and professional backgrounds in engineering.[176] NASA had meant to train astronauts for every single contingency the mission might face, and every astronaut who would go to the Moon also engineered some part of the hardware. Astronauts took part in the process of designing, building, and testing every part of Apollo machinery, meaning each astronaut was an expert, more or less, at some aspect of spaceflight.[177] On Apollo 11, each astronaut personally played a role in the first mission to land a person on the Moon, and they were instrumental in the technical plans of a lunar landing. They had proved to be the best in their field.

Edwin Eugene Aldrin, Jr, (b. January 20, 1930) known by most as Buzz Aldrin, represented the solution that NASA used to face the challenges of a lunar mission. His choice as an astronaut for a Moon mission was more about his technical contributions to the young field of astronautics, and he was very much a military man. Aldrin graduated from West Point in 1951, flew combat missions in F-86s during the Korean War, and worked with more jet fighters for the U.S. Air Force. But ultimately, it was with his Bachelors in Science in Mechanical Engineering, and later, his doctorate in Astronautics from the Massachusetts Institute of Technology, that NASA needed. While NASA rejected Aldrin's application for the astronaut corps when he applied for the Gemini program, his dissertation, "Line-of-sight guidance techniques for manned orbital rendezvous", demonstrated to NASA that Aldrin had the intellectual vision to be an astronaut.[178] He was, after all, the first to ever receive a doctorate in astronautics. This proved enough for the complicated task of a lunar landing. Despite never being a test pilot, Aldrin was chosen as part of the Third Astronaut Class.[179] Aldrin's dissertation also demonstrated his passion, as the dedication of his thesis in January 1963, put it: "In the hopes that this work may in some way contribute to their exploration of space, this is dedicated to the crew members of this country's present and future manned space programs. If only I could join them in their exciting endeavors!"



Aldrin

The inclusion of Aldrin in the astronaut corps signaled a new direction for NASA's planning. While NASA had included engineers before, key among them Gus Grissom, the inclusion of Aldrin into the corps was a recognition of the giant leap NASA must undertake to make a Moon landing successful. At this point, the American space agency was undecided on the plan to reach the Moon. Would it be an Earth Orbit Rendezvous between spacecraft, or would it take place in Lunar Orbit? In 1963, NASA could have gone either way, and even Direct Ascent was not out of the picture yet. NASA realized they had not pulled off any orbital rendezvous at all between spacecraft, and Aldrin

was picked in order to make the docking between craft a very real possibility, regardless of the location of the rendezvous.

Aldrin discovered during the writing of his astronautical thesis something he called the “orbital paradox”, and his discovery proved to be a formative step in the direction of a successful moon mission: “If you're trying to pilot your orbiting spaceship to reach a spaceship in a higher orbit, the intuitive course is to (1) aim your spacecraft up, towards the higher orbit, and (2) speed up your spacecraft so it will catch up. Dr. Aldrin describes the surprising result of this maneuver. You'll ‘end up in an even higher orbit, traveling at a slower speed and watching the second craft fly off into the distance.’”[180]

Aldrin’s genius was coming up with a way to train astronauts to dock with a spacecraft using direct observation of the target vehicle. This line-of-sight method would not be done alone; the pilot would use their direct visuals to complement and augment the computers on board the spaceship. Navigation would be a two-part act between man and machine, but Aldrin felt the combination not only made orbital rendezvous easier but also allowed astronauts to actually pilot the craft. Aldrin intended to train astronauts to ignore their “intuitions as fighter pilots” in space, “a world of three dimensions” where “there was no up and down.” They should be able to manually fly their craft and dock with another during a Moon mission, even in an emergency without help from a computer.

Aldrin’s intent to train an astronaut to manually fly the craft was more in line with the endless disagreements between the engineers and the astronauts. “There will forever be disagreements over who, exactly, flies NASA ships -- the engineers on the ground, or the spacemen in the capsules. Later in life, as most of his colleagues continued to claim the pilot role, Aldrin sided with the engineers: ‘Gemini and Apollo were computerized and pre-planned, so the era of the pilot in command, having the creativity to decide what he wants to do -- that’s gone. Only in an emergency is it apparent. And in an emergency, like Apollo 13, they had no idea what went wrong. It was like, ‘We have a problem, all the lights are comin’ on!’ And it was up to the ground to figure out what the problem was’”[181]

If Aldrin appeared to side with the engineers, he didn’t have the chance to

act like one during Gemini 12, when he and James Lovell launched into space on a 4-day mission in 1966. In addition to performing a 5 ½ hour spacewalk, necessary for any moon mission that involved two spacecraft, Aldrin was forced to manually dock the Gemini spacecraft with the Agena docking vehicle.[182] Without the targeting, it was left up to Aldrin to perform what he had originally designed: the successful training of an astronaut to pilot a craft in conjunction with a computer and navigational charts. Aldrin, in a sense, stood somewhere between the engineers and the astronauts, both of whom "honored" his obsession with orbital rendezvous with the moniker "Dr. Rendezvous."[183] Nelson noted, "As an astronaut, Aldrin revealed both his smarts and his simultaneous lack thereof in promulgating his MIT studies so assiduously and his opinions so stubbornly that it annoyed many of his colleagues. 'His doctoral thesis on space rendezvous...made him, in his own eyes, one of the world's leading experts,' flight director Chris Kraft said. 'Before long, the real experts...were calling him, with a touch of sarcasm, 'Dr. Rendezvous.'"[184]

Ironically, Aldrin's authorship of orbiting rendezvous would make the Gemini Program successful. Gemini has long been considered a mixed bag, but it did what it had to do. First and foremost, it showed that orbital docking between two craft could be achieved, or at the very least, it showed the U.S. could achieve this feat (the Soviets had also proved to be successful at this space endeavor). Second, it settled once and for all that orbital rendezvous, at least in Earth orbit, could be attempted and completed. By orbiting around the Earth, Gemini almost accomplished something that had never been intended; it very nearly made the Apollo Program and the idea of LOR redundant. For a brief time, the idea of EOR seemed to work just fine, and at one point Gemini was seen as the craft to get Americans to the Moon first.

Gemini was referred to as "Mercury Mark II" upon inception, but the program always had an initial identity that differentiated the spacecraft from Mercury. From the beginning, James Chamberlin and the manufacturer of Gemini, McDonnell Aircraft, considered Gemini as a viable option and competitor to the Apollo program that could accomplish a Moon landing at just 5% of the cost. They also thought Gemini could get men to the moon by 1966. Gemini would take advantage of the work on the Saturn (C) rocket, which in early 1960 was seen as one part of the larger vehicle for a Direct

Ascent. Gemini took life as a docking craft, and then it evolved into a fleet of craft to dock with “trans-stage target vehicles” (upper stage Centaur rockets) to accomplish lunar flybys.

Eventually, Chamberlin attempted to combine Gemini with the Apollo program in order to take advantage of the successes with the Saturn rocket. Gemini II was always billed as a possible Direct Ascent craft that could land on the Moon as a capsule with retrograde stage, upper stage ascent module, and foldable landing legs. The options to use different modules with “advanced” Gemini envisioned a fleet of craft -- “Big Gemini” -- that could rendezvous with space stations, ferry passengers from low to high orbits, and even provide a lifeboat and rescue craft for Moon explorers. To Chamberlin and McDonnell Aircraft, Gemini was the modular craft that NASA could use for years to stake a hold in Earth orbit and on the surface of the Moon.[185]

Gemini’s potential never overcame the vision that Apollo encapsulated in a design that allowed the engineers to develop visionary craft to undertake LOR -- which NASA grew increasingly fond of -- and work with a large booster, the Saturn V (C-5) that promised to launch even more ambitious spacecraft than Gemini could. As a government project, the Apollo program was unrivaled and even considered a logical successor to the Manhattan Project, with the engineering and government assisted programs and agencies the program created and supported over the decade.[186] As Nelson put it in *Rocket Men*, “In so many ways, the race to the Moon would turn out to be a sequel to its predecessor’s race for atomic mastery. Bother were enormous projects that only a great nation, on a federal level, could afford to attempt, and achieve. Both began with Third Reich émigrés, and a shared geography [New Mexico].”[187]

With the view of Gemini as mostly a “trainer” for U.S. astronauts, the narrative of men who traveled to the Moon makes sense and, upon first impression, follows a logical pattern. From the years 1965-1966, nine successive launches took place, and every Apollo astronaut rode on a Gemini spacecraft and participated in an ambitious schedule of experiments, maneuvers, and assessment of technology. During this time, EOR was the “cradle” for the plan to rendezvous two craft in space, and Gemini’s astronauts took part in those missions. The program had started as a

spacecraft designed to take advantage of the lessons from the Mercury Program, but also, and quite purposely, being built by astronauts with higher degrees in mechanical and aeronautical engineering. As each of Gemini's names represented the different intentions behind the program, such as "Mercury Mark II" meant to suggest its replacement of the first space capsule, the name "Gus Mobile" informed people in joking terms that Virgil Ivan Grissom, better known as Gus Grissom, had designed the spacecraft for astronauts to be more than passengers. Gemini taught astronauts how to *fly* in Earth-orbit.[188]

Neil A. Armstrong (August 5, 1930 – August 25, 2012) got his bachelor's degree in aeronautical engineering and master's in aerospace engineering, which gave him the solid foundation he would need to contribute to the U.S. space program. He did so immediately by joining the National Advisory Council for Aeronautics (NACA) from 1949-1952.[189] He took the knowledge he gained as a naval aviator to NASA's "High Speed Flight Station." In the spot that was to become the Dryden Flight Research Station, Armstrong flew 200 models of experimental aircraft over the Mojave Desert, including jets, rockets, helicopters, and gliders. He even test piloted the 4000 mph X-15 and the Dyna-Soar, the Air Force's attempt at a winged suborbital spacecraft.[190] Armstrong explained, "I did a lot of different test programs in those days. That was the first time I ever flew supersonic. We had two B-29s that were sued for dropping rocket aircraft, the X-1s and the Skyrockets. So I, either as the right-seat or the left-seat guy in the B-29, launched over one hundred rocket airplanes in the fifties."[191]

Neil Armstrong

While fellow astronauts would later comment that Armstrong was viewed as the “weakest” on the “[steering] stick,” Armstrong came to the astronaut corps in 1962 with multiple levels of experience. His flight-time with diverse craft not only allowed him to handle different engineering characteristics but also gave him moments to work through unexpected malfunctions and other non-operable problems. “Inside the small world of military aviation, his exploits as a test pilot are still spoken of with awe. One of the stories that is told is that after landing a plane in the desert after its engines had both failed, Armstrong was rolling to a stop when he saw an obstacle that he was about to crash into. According to the legend, he used his speed and the flaps and rudders of his aircraft to force the plane up onto one wheel and, like a movie stunt driver, swerved around the obstacle precariously balanced on a single

bit of rubber."[192]

Mechanical challenges forced Armstrong to think quick, make rapid decisions, and possess the coolness and acumen to take control of an aircraft. His colleagues recognized his skills in those regards quickly.[193] After Armstrong's death in 2012, Buzz Aldrin called him the "best pilot I ever knew." An article in *The Daily Beast* noted, "His skill as a research and test pilot certainly impressed Buzz Aldrin...Aldrin said in an interview with The Daily Beast shortly after his former colleague's death. That is high praise indeed coming from a man who had flown F-86 jet fighters in combat in Korea and who has his own impressive set of flying and technical academic credentials. Armstrong's ability to memorize the smallest engineering detail and to be able to explain, in even more detail, the intricate working of any aircraft he tested made him the outstanding test pilot of his generation. To this day, within military aviation, he is famous for his "steel trap" mind and his unflappable demeanor."[194]

After his arrival with the second class of NASA astronauts, Armstrong flew on Gemini VIII in 1966 as the command pilot. It would be Gemini's sixth manned flight, but the first to dock two spacecraft. Along with his pilot, David R. Scott, Armstrong would dock the Gemini capsule with a Gemini Agena Target Vehicle (GATV). The launch of both spacecraft went flawlessly, and the docking commenced without a hitch. Aided by computers and navigation software, as well as Aldrin's "training for orbital rendezvous", Armstrong was the first astronaut to pilot a craft and dock it with another spacecraft.

For 27 minutes, the mission proceeded as planned. Scott prepared for a two hour spacewalk, partly in preparation for expectation of EOR and the training for a lunar mission. Suddenly, both spacecraft began to tumble wildly and out of control. Armstrong immediately detached from the GATV, but the tumbling continued and then intensified. Gemini VIII was out of control.[195] An article in *Discovery* described the situation:

> "The men in Houston got confirmation that the spacecraft had separated just as Armstrong pulled the Gemini back and Scott hit the undock switch. Unfortunately, the separation didn't help the astronauts. Scott called down as calmly as he could, 'We have serious problems

here. We're– we're tumbling end over end up here. We're disengaged from the Agena.' They tried to explain to mission control what was happening. 'We're rolling up and we can't turn anything off,' Armstrong said. 'Continuously increasing in a left roll.' Armstrong fought without success to dampen out the spacecraft's tumbling. Turning things over to Scott didn't help; he was equally unsuccessful. By then, Gemini 8 was making one full revolution *per second*. The centrifugal force building up inside the spacecraft was making loose items — flight plants, checklists, and procedure charts — stick to the walls. Their heads and arms were pinned against the backs of their seats making reaching the hand controllers an effort. The sunlight coming in through the windows was flashing as fast as a strobe light.[196]

Gemini VIII

The only thing Armstrong could do was end the flight and begin re-entry, since the alternative of Scott and him struck by a blackout would have

doomed them. He reached back behind his seat and felt for the re-entry control system. Once engaged, the spacecraft stopped its tumble, and Scott fed line code into the computer to program new re-entry information. Gemini splashed down on Earth, and the investigation began. It turned out one of Gemini's eight control thrusters had been stuck in the on-position. When it fired thrust repeatedly, the spacecraft had responded by tumbling, but the crew of Gemini VIII had survived through their grasp of the situation and the creation of a solution to save the capsule. Armstrong's training as a pilot proved to be the most crucial factor. By avoiding a catastrophe, Armstrong had also kept NASA on track with its projected mission schedule for the Moon.[197]

A great deal of anxiety surrounded NASA about the quality of the rockets and spaceships, the training of the ground crews and astronauts, and the coordination between humans and computers. For Apollo, disaster was much closer to reality than anyone wanted to admit. Already, tragedy had struck the program during Apollo 1.

Two things happened that put Apollo on course to land on the Moon. The first was Apollo 8, the first all-up mission of a Saturn V and a crewed ship towards the Moon. Understandably, most people can name Apollo 11 as the first mission to land men on the Moon, and a critically acclaimed film about Apollo 13's harrowing mission was released in 1995, but this has also meant that the rest of the Apollo missions have been greatly overshadowed, including Apollo 8, despite the fact Apollo 8 accomplished several firsts and ultimately made Apollo 11 possible.

NASA launched Apollo 7 on October 11, 1968. Apollo 7 was a manned mission that tested the command/service modules in Earth's orbit and reentry. The successful mission demonstrated the viability of the command/service module to enter Earth's orbit and survive reentry back into the Earth's atmosphere. Apollo 8 was originally intended to test the lunar module in orbit and reentry, as Apollo 7 had done for the command/service module, but in June 1968, NASA suffered a setback with the lunar modules, which compromised the planned December 1968 date for Apollo 8's launch.

Since the lunar modules weren't ready, and the command/service modules had already been successfully tested in Earth's orbit and reentry, NASA

decided in August to change Apollo 8's mission, making it a manned mission to orbit around the Moon in the command/service module. This would allow NASA to test the command/service module's lunar orbit procedures, and, of course, score a huge propaganda victory in the Space Race.

On December 21, 1968, Apollo 8 was launched by a Saturn V rocket. All three stages of the Saturn V rocket had been tested in previous launches, including the crucial third stage that had to reactivate to accelerate the spacecraft out of Earth's orbit and toward the Moon. The previous unmanned mission suffered a failure of the third stage's Trans Lunar Injection sequence, but the Saturn V carrying Apollo 8 worked almost perfectly. About three hours after launching, the Apollo 8 crew became the first humans to escape Earth's orbit and take pictures of the entire planet as a whole.

Apollo 8 cruised toward the Moon for nearly three whole days before it was time for the Lunar Orbit Insertion. Four minutes later, the crew became the first humans to enter the Moon's orbit and see the far side of the Moon in person. While orbiting, the crew reconnoitered the Moon's surface, eventually describing the "Sea of Tranquility" well enough that it would become Apollo 11's planned landing site.

As Apollo 8 continued orbiting around the Moon, it witnessed the Earth rising and snapped the iconic "Earthrise" photo of the globe from the Moon's vantage point on December 24. On Christmas Day, after several orbits around the Moon and the first ever live broadcast interview from the Moon's orbit, Apollo 8 prepared to head home.

On the voyage home, crewmember Jim Lovell inadvertently switched off certain navigational readings for the module's computers. This accident required using the module's thrusters to manually realign the spacecraft for reentry. The mistake was quickly corrected, but it fortuitously gave Lovell the experience to do it for Apollo 13 under more trying circumstances.

On the afternoon of December 27, 1968, Apollo 8 splashed down safely in the Pacific Ocean. In addition to setting history, the three crewmembers, Lovell, Frank Borman and William Anders, were named Time's Men of the Year.

The success of a mission that orbited the Moon and returned home

reinvigorated NASA and the Apollo Program. The success of the mission proved what many at NASA had said for a year. Saturn could launch men to the Moon; and the Soviets and their N-1 booster -- it continued to explode on the launch pad or fall back to the Earth. It seemed the U.S. had the space it needed to beat the Soviets.[198] All that was left was to launch and pilot Apollo 11.

Picture of Earth taken by Apollo 8

Apollo 8’s success had also benefited its backup crew, which included Neil

Armstrong and Buzz Aldrin. Neil Armstrong later explained:

> "We were very excited about [Apollo 8]...We thought it was very bold, because we still had the problem on the Saturn and we'd had a couple problems with [both] Saturn V launches, so to take the next one, and without those problems being demonstrated as solved, and put men, a crew on it, not just take it into orbit, to take it to the Moon, it seemed incredibly aggressive. But we were for it. We thought that was a wonderful opportunity. If we could make it work, why, it would make us a giant leap ahead. It showed a lot of courage on the part of NASA management to make that step. One of the things I was concerned with at the time was whether our navigation was sufficiently accurate, that we could, in fact, devise a trajectory that would get us around the Moon at the right distance without, say, hitting the Moon on the back side of something like that, and if we lost communication with Earth, for whatever reason, could we navigate by ourselves using celestial navigation. We thought we could, but these were undemonstrated skills."[199]

The Gemini program prepared to conclude its original mission objective as a trainer of Apollo astronauts in the year 1966, and the 10th mission rocketed into space carrying astronauts Michael Collins and John W. Young. They had a full mission in front of them, charged with the accomplishment of former Gemini objectives left unfulfilled by the cancellation of missions. Collins and Young's flight had big ramifications that made Apollo 8 successful, including the ability to dock with an Agena module, fire the module's rockets, achieve a higher orbit to rendezvous with another Agena module (one that was derelict and without radar) and perform a space walk over to the module. Every step that Gemini X achieved gave NASA the confidence that Apollo 8's lunar flyby could be completed. So successful was Gemini X that NASA would give Collins the responsibility as the command/service module (CSM) pilot on Apollo 8.

Michael Collins

An emergency back surgery took Collins off the mission and nearly ended his astronaut career, but his recovery allowed NASA to put him back won the Apollo Program and on the next available mission for the Moon. With Apollo 10's successful mock-up and rehearsal for the Moon landing in lunar orbit, NASA could put Collins in the pilot seat of the CSM *Columbia* on Apollo 11. [200]

Michael Collins (b. October 31, 1930) was a rarity among NASA astronauts. He was a United States Air Forces test pilot, far different than the greater pool of pilots NASA recruited from, which typically included aviators from the Navy and Marine Corps. His 5,000 hours spent in the air gave him excellent control of the "stick," which led to his inclusion in the Astronaut Group Three of 1963 and made him one of the best pilots in NASA.[201] He was used to carrying out experimental missions and was perfectly

comfortable in that capacity. He would be required to accomplish pilot-tasks that no other aviator had ever done, primarily the one thing no Apollo mission could test for: the rendezvous with a lunar module on-return from the Moon with two astronauts onboard. Years later Collins remarked on the test of his skills as an aviator he would most likely be remembered for: “My secret terror for the last six months has been leaving them on the Moon and returning to Earth alone; now I am within minutes of finding out the truth of the matter...If they fail to rise from the surface, or crash back into it, I am not going to commit suicide; I am coming home, forthwith, but I will be a marked man for life and I know it.”[202]

A good solution for Collins to avoid the infamy of “stranding” Armstrong and Aldrin on the Moon lay with the Guidance and Navigation system. Computers and navigation software were one part of it, and gyroscopes also helped a pilot keep track of the three-dimensions of outer space; but it was the experience of Collins that made the difference in the success of Apollo. Collins, like the Apollo astronauts before and after him, would wear an eye patch to avoid the fatigue of endless hours of squinting. He peered through the ship’s sextant to sight stars in the night sky, no different than navigators had done for hundreds of generations on board sailing ships. When he located the position and altitudes of the stars, he combined the results with the onboard data of the ship’s speed and position. The purpose of this was to fire the CSM’s rocket and send Apollo 11 on its course to the Moon.[203]

The Guidance and Navigation unit was only as good as its human operator, and that responsibility also lay with Collins. When the gyroscopes were correctly set, Collins was in charge with the dial-in of the position of the two reference stars. The navigation system would then compare the ship’s position with the Inertial Measuring Unit, and the thrusters were fired to set the ship on its course. The problem with this, as Apollo 8, 9, and 10 learned, was that the amount of sunlight hitting the spacecraft made it difficult to recognize stars without the surrounding constellations. Collins proved good at using the sextant’s computer to find the stars.[204]

Collins’ proficiency with the challenges of flight and navigation worked to ease the many problems Apollo faced in landing men on the Moon. For one, serious gaps in knowledge about the Moon’s composition challenged NASA,

and that serious lack of data could potentially compromise the mission. The Ranger and Surveyor probes had done an excellent job mapping the Moon, but the astronauts had a feeling that, along with their training, there was not enough knowledge of the surface terrain to inform targeted landing sites.[205]

Collins also worried about things out of his control, mainly the technologies that were responsible for landing the LEM *Eagle* on the Moon and the return trip. The LEM's upper stage, the vehicle responsible for the delivery of Armstrong and Aldrin from the Moon's surface to the CSM in orbit, had developed an instability. Sometimes during dress-rehearsals, it would not separate from the descent stage. This would have trapped the astronauts on the Moon.[206]

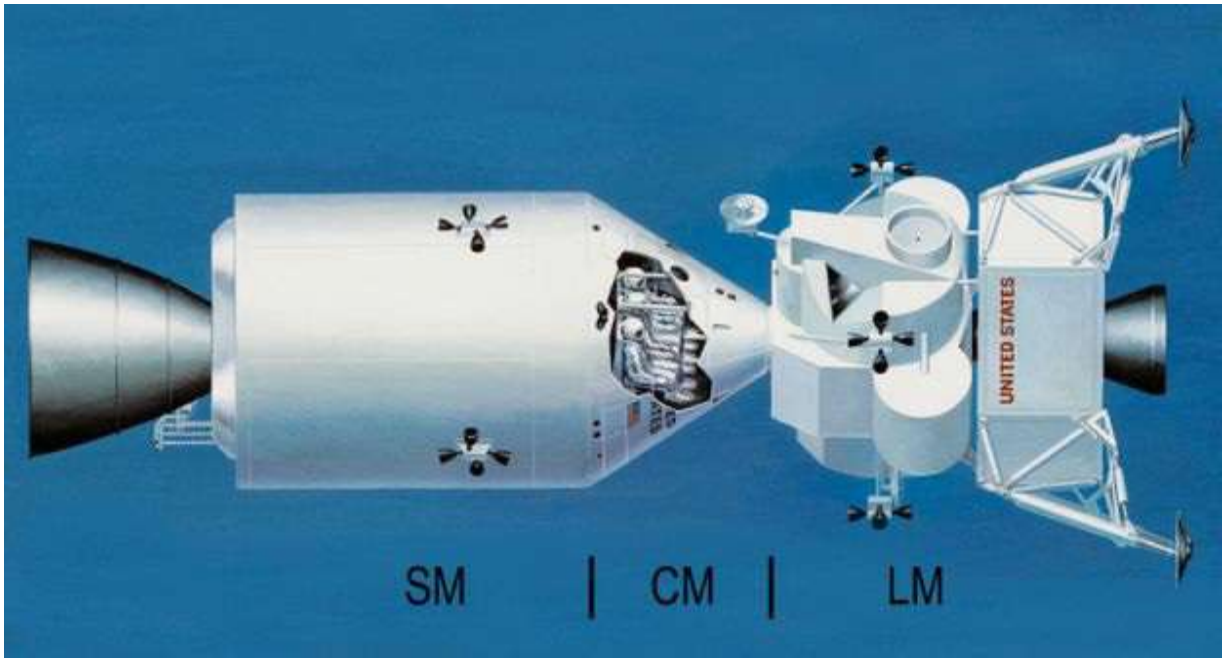
Another issue that developed belonged to the contingencies of things the engineers at NASA could not plan for and would only know at the moment of truth, when the *Eagle* was on its way to the lunar surface. Engineers questioned whether imaging radar would work on the LEM, and whether or not the data could be simultaneously communicated with the CSM and Mission Control back on Earth.[207] The matter of docking the *Columbia* and *Eagle* also gave NASA fits, as the history of near disasters during rendezvous and space walks had never been completely solved. Most astronauts had gotten sick during EVAs outside of their spaceship, as the strain to maneuver in zero gravity fatigued them. NASA knew in an emergency that EVAs might be all that could save the crew, especially if Armstrong and Aldrin had to move from the LEM to the CSM.[208]

NASA flight managers and Apollo astronauts, aware of all the things that could go wrong, counted on the skill and dedication of professionals like Collins to offset the challenges and dangers that could potentially destroy the mission. His position as the CSM pilot carried a great honor and responsibility. No astronaut could pilot the capsule unless they had done before. At that time in the flight order of Apollo astronauts, none had, so Collins was the only astronaut who NASA felt could be entrusted with the job to circle the Moon alone and await the two astronauts who would descend to the surface and hopefully return. As Armstrong put it:

> "I was certainly aware that this was a culmination of the work of 300,000 or 400,000 people over a decade and that the nation's hopes

and outward appearance largely rested on how the results came out...And you know, I have no complaints about the way my colleagues were able to step up to that....when you have hundreds of thousands of people all doing their job a little better than they have to, you get an improvement in performance. And that's the reason we could have pulled this whole thing off...when I was working here at the Manned Spacecraft Center, you could stand across the street and you could not tell when quitting time was, because people didn't leave at quitting time in those days. People just worked, and they worked until whatever their job was [was] done...And whenever you have those ingredients, whether it be government or private industry or a retail store, you're going to win."[209]

Apollo 11



The service module, command module, and lunar module design for Apollo 11

At the end of 1968, the country was celebrating the historic and successful Apollo 8 mission, as was NASA. But NASA also realized that the mission only occurred due to a setback with the lunar module that would actually land on the Moon. In March 1969, the unheralded Apollo 9 tested the lunar module's maneuvers for several days in Earth's orbit before successfully reentering Earth's atmosphere.

By May 1969, NASA was ready to do an entire dry run of landing men on the Moon. Apollo 10 was sent into lunar orbit with the command/service module and lunar module, and on May 22, a lunar module descended toward the Moon for the first time. The lunar module was manned, but the ascent stage was not fully fueled, so it could not complete an entire descent. The automated system worked, and the modules successfully re-docked together. Apollo 10 successfully splashed down on May 26, and with that, NASA was ready to land men on the Moon.

Before Collins could pilot the CSM with attached LEM to the Moon, the Saturn V booster needed to accomplish the most dangerous part of the

mission: the launch. The astronauts rode the high-speed elevator 320 feet to the Apollo capsule and strapped into their flight seats. The countdown began at 2 hours and 46 minutes. The Soviets struggled throughout the 1960s to design rockets up to the task, but NASA got it right with the Saturn V rocket, which to this day remains the most powerful launching rocket NASA ever used. The Saturn V rockets were truly gargantuan, standing nearly 350 feet tall and holding thousands of tons of fuel. These rockets could carry a payload weighing over 250,000 pounds into orbit, giving it the ability to launch the Apollo spacecraft into orbit in about 12 minutes at nearly 18,000 miles per hour. But that was just the beginning of the Saturn V's duties. Once in orbit, the Saturn V still had to accelerate the spacecraft to nearly 25,000 miles per hour to allow the spacecraft to escape the Earth's orbit and head for the Moon.

Designing rocket engines that powerful was hard enough, but NASA had to design the Saturn V to accomplish its duties in multiple stages, because an Apollo spacecraft typically had to spend a few hours in orbit around the Earth before heading for the Moon. Thus, the Saturn V's first two stages would accelerate the spacecraft to about 15,000 miles per hour, while the third and final stage would enter the spacecraft into Earth's orbit at about 18,000 miles per hour. But this third and final stage also had to be capable of essentially restarting and reaccelerating to propel the spacecraft out of Earth's orbit and to the Moon at about 25,000 miles per hour. Not only was Saturn V capable of getting the job done, but it also got the job done successfully every time it was used. NASA relied on Saturn V rockets more than a dozen times without a major accident during the 1960s and 1970s.

With the last adjustments made to leaky hydrogen fuel valves, the five mammoth F-1 engines fired. The rocket lifted, moving slightly -- some astronauts called it a faint 'wobble' -- and the rockets gimbaled slightly to keep everything on course. Nothing held the spaceship upright but the columns of thrust. A launch controller said the words the crew most wanted to hear: the rocket had cleared the tower. Within seconds, Apollo 11 was lifted hundreds of feet into the air and its auto program began a roll. The ship was on course towards the first objective. The first stage of the Saturn V rocket would accelerate the spacecraft to over 6,000 miles per hour in two and a half minutes before detaching and falling away. The second stage

accelerated the spacecraft to about 15,000 miles per hour after six more minutes before falling away. If all went well, Apollo 11 would orbit the Earth in a little more than 11 minutes.[210]

The Launch Control Center before liftoff

After two orbits of the Earth, Collins was commanded by Houston Control to ignite the third stage of the Saturn V, known as the “Translunar Injection”. This stage would accelerate the spacecraft to about 25,000 mph to reach the escape velocity necessary to escape Earth’s orbit. At this time, the lunar module attached to the service/command module, and once the spacecraft reached escape velocity, the Saturn V’s third stage fell away on a different trajectory.

Apollo 11’s picture of Earth during the Translunar Injection

The engines fired on and shot Apollo 11 on its course to the Moon, a journey that would take three days of cruising and a short engine burst known as the “Lunar Orbit Insertion” procedure to properly position the spacecraft to be captured by the Moon’s orbit. NASA had mapped the Moon during previous missions, in order to help choose the landing sites for the Apollo lunar modules. When the Moon captured the spacecraft, the spacecraft would complete several orbits around the Moon to properly line up the lunar module for descent.

As this part of the journey began, Aldrin turned on the color camera inside the capsule, and already viewers on Earth witnessed the historic trip that might or might not land men on the Moon. Of course, one thing the camera could not capture was the mental state inside the capsule. Nelson captured the mood in *Rocket Men* by describing how Collins felt about the other two astronauts:

> "Of the three, Collins was always the 'easy-going guy who brought levity into things,' as Buzz Aldrin recalled. During the run-up to their mission, Collins tried to foster a sense of camaraderie, but could only get so far. After Armstrong's bulwark of shyness proved impenetrable, Collins decided that Neil 'never transmits anything but the surface layer, and that only sparingly. I like him, but I don't know what to make of him, or how to get to know him better.' He doesn't seem willing to meet you halfway...Buzz, on the other hand, is more approachable; in fact, for reasons I cannot fully explain, it is me that seems to be trying to keep him at arm's length. I have the feeling that he would probe me for weaknesses, and that makes me uncomfortable."[211]

Perhaps the astronauts, much to the chagrin of the "easy-going" Collins, were men much more comfortable with their thoughts. The view of the Earth from orbit had already inspired the crew and left them to ponder the "imaginary lines that you can't see."[212] Once on the way to the Moon, though, having left the Earth behind, no reference points existed. Only the blackness of space awaited them; and the spaceship was engulfed by the expanse of dark and the glitter of stars.[213]

All the crew could do at this point was go through their various duties; Collins attended to the tasks of purging fuel cells, dumping wastewater, recharging batteries, and replacing carbon dioxide filters. Armstrong and Aldrin went over procedures to land. They also had to eat. "On Apollo 11, ham, tuna, and chicken salad sandwich spreads were squeezed out of a tube...Freeze dried entrees...of roast beef, ham, potatoes, yam, bacon, applesauce, vegetable medley, and hash were vacuum-sealed in plastic and needed to be rehydrated with three shots of hot water and kneaded into a mush, which was then, again, squeezed out like toothpaste."[214]

Still, the astronauts on Apollo 11 enjoyed the trip, especially the sensation of weightlessness,[215] and Apollo 11 experienced a unique visual phenomenon on the way to the Moon. The further the ship traveled, the harder it became to see the Moon. Collins pitched the ship so the crew could have a view of their destination, but they did not have much time to appreciate the view. On July 19, the fourth day of the mission, they would make the burn of the CSM's single thruster to achieve orbit. This, like other events on the trip, was the moment of truth. Either Apollo 11 would successfully enter the orbit of the Moon in order to land on the surface, or the burn would fail and they would have to abort the mission.

NASA soon received the signal from the dark side of the Moon, where Apollo 11 had now entered. They were "go" for lunar orbit. The mission to land on the Moon was still on.[216]

Looking out over the lunar surface, the crew lauded the near-perfect precision of the orbital insertion and compared notes about their perceptions of the Moon's "true" color. NASA asked them to identify the "landing path," and the crew looked for identifying craters, with a sudden panic at the realization that the topography nearly looked identical from one section to the other. Collins and Armstrong eventually made headway of the location of their bearings, but they quickly realized the Moon's true mystery. To the astronauts, the Moon was an "unwelcoming" and "unfriendly" place.[217] Collins later reflected on that moment, "I feel that all of us are aware that the honeymoon is over and we are about to lay our little pink bodies on the line...We have not been able to see the Moon for nearly a day now, and the change is electrifying....The Moon changes character as the angle of sunlight strikes its surface changes....It starts off very forbidding, becomes friendly and then becomes forbidding again as the Sun disappears."[218]

Indeed, Collins was right. The moment came to put their "little pink bodies on the line." After 13 orbits around the Moon, Armstrong and Aldrin dressed in the EVA suits, also known as "white, thirteen-layered, Mylar-and-Teflon-coated beta-cloth Integrated Thermal Meteoroid Garments."[219] Both astronauts took their positions inside the LEM *Eagle*. Collins also had to dress-up in a spacesuit, just in case he needed to make an emergency spacewalk.

To descend thousands of feet down to the Moon's surface, the lunar module had both an engine and thrusters that would allow it to maintain speed, control and direction. The lunar module would descend in a pirouette to help it descend straight, but as Apollo 11's lunar module inadvertently proved, any incorrect timing or ill-timed thrust would land a module several miles away from its intended destination, which could be the difference between a smooth landing or landing among boulders and craters. For most of the descent, the lunar module was automated, but the final stage of the descent required manual controls, and once the descent stage was finished, it would fall away from the module like the Saturn V rocket stages.

Armstrong and Aldrin did not sit down in the cockpit; they would fly the *Eagle* in an upright position, velcroed and tethered to the walls and floors. The LEM's appearance was function over form, appearing almost like an

insect. It had the thinnest of skins, consisting of barely three sheets of aluminum foil. As one engineer explained, “aesthetics be hanged.” The bug-eyed lander would accomplish the final vision of NASA’s moon mission and land two men on the Moon by operating like a dinghy. The lower descent engine and stage would be left on the surface, and the ascent stage would bring the astronauts back to the *Columbia,* only to be cut loose and left to drift away into space.[220]

Once Collins blew the explosive bolts, the *Eagle* now operated under its own electrical power. Armstrong swiveled the LEM around, so Collins could check the full deployment of its landing legs. Armstrong, as mission commander, gave the signal, “The Eagle has wings.”

Now came the moment no amount of simulation could have anticipated, and the moment NASA and the astronauts feared most of all. No matter the amount of training, fine tunings in orbital calculation and speed were still not as exact as mission planners would have liked. And sure enough, the first problem of the many still to come occurred when the separation between *Columbia* and *Eagle* created more thrust than intended. Along with the mistakes in calculating the gravity of the Moon and its influence on the ships, this ensured the original landing site would be overshot by four miles, setting the *Eagle* on a path towards a field of boulders.[221]

Back on Earth in Houston at Mission Control (MOCR), a sprawling community college-like campus, the situation was closely monitored by an imaginative and dedicated corps of controllers who prided themselves on their ability to solve problems. They now would have one. In front of the 20x10 foot screen showing the two tiny dots that were *Columbia* and *Eagle* flashing slowly across a giant picture of the Moon, the controllers sat in a place nicknamed the Trench. Each one’s role was designated by terms like “FLIGHT,” “CONTROL,” “FIDO,” “TELMU,” and “GUIDO.” Flight dynamics officers, guidance and navigators imagined themselves as pilots on the spacecraft, in an effort to be so involved in their responsibilities that they literally connected with each phase of the mission.[222]

However, none of them realized that the *Eagle* would overshoot its landing target, because they were too wrapped up in another dilemma: Mission Control had lost radio contact with the *Eagle*. The controls then made a

succession of confirmations, whether the *Eagle* could continue its powered descent and land, or whether or not to abort the mission. Given the choice of "Go/No Go," the responses were unanimous. A solution to the problem had lay with using Collins in the CSM to relay Mission Control telemetry to the LEM. The mission could continue. The flight controllers were all "Go." Collins relayed the message to the *Eagle*, "*Eagle, Columbia*. They just gave you a go for powered descent...*Eagle*, do you read *Columbia*?" Aldrin sent back the response, "We read you."[223]

Aldrin called off the instrument readings for Armstrong to pilot the craft, who by this time already realized they would overshoot the target area by almost four miles. MOCR realized the issue too as the *Eagle* sped over the surface of the Moon much faster than anticipated. MOCR considered aborting but waved it off. The controller responded with "GOs", and MOCR then lost contact with the LEM again.[224]

Making matters worse, computer alarms began to sound off. First came "Error 1202." MOCR learned of the programming error, knowing a computer malfunction would stop the mission, and both Apollo astronauts and flight controllers had trained for these alarms. In simulations, they had faced every single imaginable situation that could go wrong with the computers, and what they had learned instructed them for their next decision: "Go/No Go". As MOCR conferred with each other, Aldrin and Armstrong continued to descend rapidly to the Moon's surface.[225] Aldrin would later state, "During the descent, when were started having problems with the computer, my attention was focused entirely inside the cockpit looking at the displays and trying to relay the information on the computer and also on the altitude and altitude rate meters to Neil so he could use this with his out-the-window determination as to where we should go to find a suitable landing place. Things were happening fairly fast and it was just a question of making sure the most correct thing was done from my standpoint at that instance. Not much time was allowed for reflection on the situation."[226]

Then another error alarm sounded, "1201." Guidance and Navigation in MOCR reflected on the simulations training sessions for what seemed to Armstrong to be an unbearable amount of time. He asked for a reading, concerned that the powered descent could not continue. Armstrong later

explained, “The concern here was not with the landing area we were going into, but, rather, whether we could continue at all. Consequently, our attention was directed toward clearing the program alarms, keeping the machine flying, and assuring ourselves that control was adequate to continue without requiring an abort. Most of the attention was directed inside the cockpit during this time period and, in my view, this would account for our inability to study the landing site and final landing location during the final descent. It wasn’t until we got below two thousand feet that we were actually able to look out and view the landing area.”

After 15 minutes of deciding, MOCR finally concluded that the computer alarm signaled the computer’s difficulty with complex commands. The guidance system was being flooded by too many commands, and MOCR reassured *Eagle* that it could continue the descent. Armstrong still had control, and MOCR gave him another round of “GOs.” Powered descent continued.

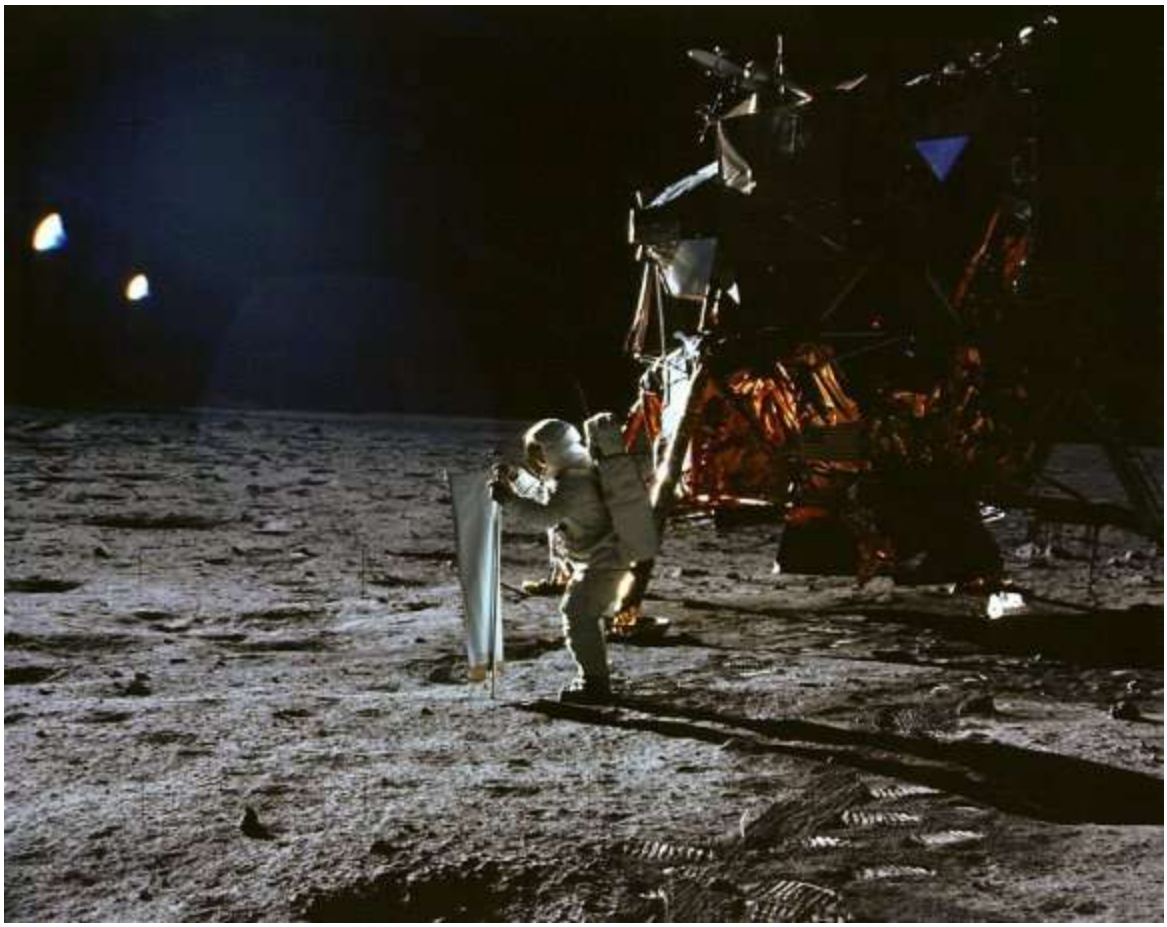
Armstrong tilted the *Eagle* into the feet-first position to land and immediately realized the terrain did not offer a place to safely land. They flew over a crater field with boulders, some the size of cars, so Armstrong continued to fly the *Eagle* horizontally. MOCR noticed his speed and the time; in every simulated landing, and by intended design, Armstrong should have landed the *Eagle* by now. Moreover, the craft was intended to land automatically. It had not, because Armstrong could not chance the site below him, so he continued to manually control the *Eagle* and skim over the top of the boulder field about 200 feet off the ground.

Armstrong had a number of other things to consider. A message light signaled a thruster shutdown, but he knew from the hundreds of flight simulations this was not the case, and because he knew that, he could continue to land. Fuel was a bigger concern. He now needed to rapidly lower the *Eagle* to the ground. At 65 feet, the LEM had 60 seconds of fuel left. With the rate of speed Armstrong had commanded the *Eagle* to move at, the craft entered the “dead-zone” quicker than MOCR liked. Even if Armstrong did decide to abort, the ascent stage would not lift them off in time to stop their descent to the surface. They would crash with fuel or without it.

These events happened without any explanation from Armstrong, so no one

in the MOCR knew why he had decided to take manual control. He never said anything, and the flight controllers only heard Aldrin call off the feet and the percent of remaining fuel: “Four forward. Four forward. Drifting to the right a little...Twenty feet, down a half...Drifting forward just a little bit; that’s good...”[227]

When Armstrong saw a clearing, he began to land, and the descent engines kicked up a cloud of dust. One of the *Eagle’s* foot sensors had made contact. Armstrong heard Aldrin call “contact” and shut down the engines before relaying a famous message: “Houston, Tranquility Base here. The *Eagle* has landed.”[228]



Small disconnects typified the momentous moment of triumph. A world celebrated, NASA fretted, Aldrin turned to his religion, and Armstrong prepared to walk out onto an alien world. While people all over the world celebrated the *Eagle’s* touchdown, MOCR had to make a decision: “Stay/No Stay.” Another problem developed immediately upon landing when a frozen

dollop of propellant blocked the descent stage engine and produced an increase in temperature. Engineers feared an explosion of the fuel vapors, but the problem solved itself, allowing Armstrong and Aldrin to resume their checklists. They would soon exit the *Eagle* and walk on the Moon's surface, but first, Aldrin took out his personal belongings and prepared to take Holy Communion.[229]

Walter Cronkite holding up the *New York Times* headline

Once the Eagle landed, the plan was to have Armstrong and Aldrin spend a few hours completely shutting down the lunar module and then get some sleep. But Aldrin and Armstrong were too excited to sleep. Armstrong prepared for several tasks before he would step out onto the Moon, and it took him and Aldrin far longer than expected -- 3 hours -- to suit up in spacesuits that would protect them. Armstrong also had to deploy the boom arm with another unique responsibility; the boom possessed a video camera to transmit the images of his first step onto the Moon. Armstrong, used to problems at this stage, also had to step a full three-and-a-half feet to the surface, but his landing was so gentle that the shock absorbers did not compress.[230]

The picture of Armstrong taken by the camera on the boom

Just before 11:00 p.m. Eastern Daylight Time, Armstrong began his exit out of the *Eagle* and onto the Moon's surface. As Armstrong was departing the *Eagle*, he activated the television camera, beginning a broadcast watched live by hundreds of millions of people. As he left his first footprint on the surface and described the dust, Armstrong then began to give his prepared statement, "That's one small step for a man, one giant leap for mankind."

Ever since, historians have debated whether Armstrong actually tripped over the statement, because the transmission sounded like he said, "That's one small step for man." The transmission quality of the video and audio was less than optimal, and some believe that a cut-out in sound produced what most people heard: "That's one small step for...man, one giant leap for mankind." Theories continue to abound about the omission of one "a" in the statement. Whether it was the transmission quality, nerves, or how a "central Ohioan" talks is a matter that might forever be unsettled. But the debate about

the missing “a” demonstrated how many people on the Earth witnessed his first steps onto the Moon.[231]

Once he had made his first step, Armstrong let MOCR know what the surface was like, transmitting the message, “Yes, the surface is fine and powdery. I can kick it up loosely with my toe. It does adhere in fine layers, like powdered charcoal, to the sole and sides of my boots. I only go in a small fraction of an inch, maybe an eighth of an inch, but I can see the footprints of my boots and the treads in the fine, sandy particles.” Armstrong would report that given the lack of gravity moving on the Moon was "even perhaps easier than the simulations...It's absolutely no trouble to walk around." Armstrong was so excited during his time on the Moon that his metabolic readings were worrying MOCR back on Earth, and they let him know about it.

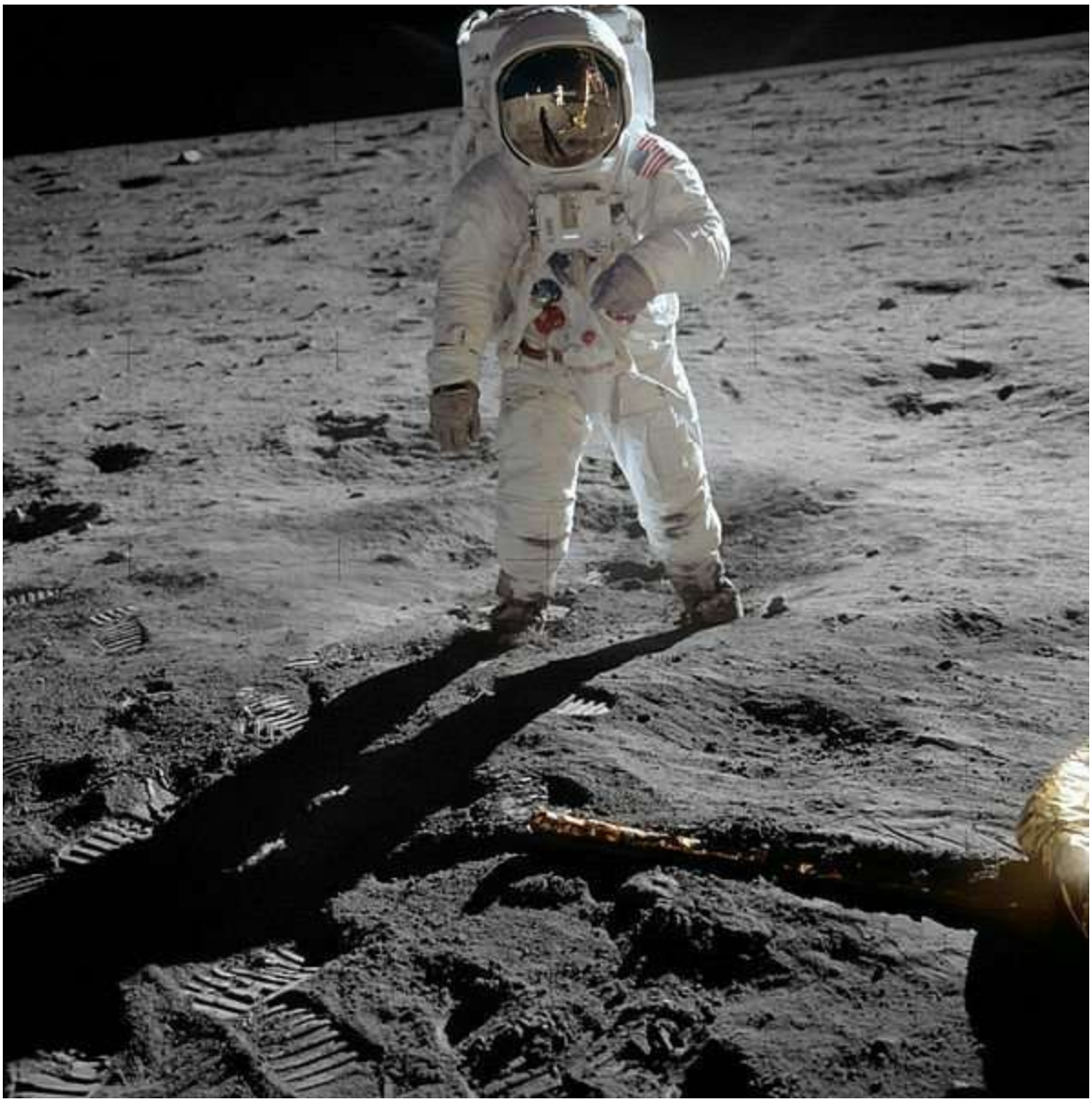
Aldrin stepped out next onto the Moon, with a reminder from the MOCR to not lock the door, since the *Eagle* did not have a handle on the outside. Aldrin passed that test and made his own “small step for a man”. He had now fulfilled his previous wish to join the “adventures” of the astronaut corps, going one step further onto another world, one he described for the ages as “magnificent desolation.”[232] Aldrin later described the feeling:

> “Well, the first thing that I wanted to do when I got on the surface was to hold on and to just sort of bounce around and check the mobility that I had and then let go and see what the footing was like. All that took was maybe 30 seconds or a minute to feel that I knew how to move around with great confidence, and that's all the later crews really needed to do. So I was doing that for my benefit but for their benefit too. And later on in the spacewalk outside, when I jumped around and pranced around, again I was doing that for the benefit of the people back on Earth to see, and to measure what the mobility was like, so that it would give something in addition to our verbal description of observations when we got back. The things that we did on that first mission I felt were done to make later missions more successful. So we would look and see what the condition of the lander was, take pictures of it, so that later on the people wouldn't have to spend the time doing that. Our mission really was to put out some simple experiments: the laser reflector, the passive seismometer, to verify that the leveling

devices and the antennas worked, to do some quick sampling of the surface. Because our lander was heavier than the later landers, we didn't have the room for the consumables, or the margin, to be able to stay out to go twice, for example, or to stay out even longer. Whatever the flight plan, and the engineers decided what our mission was going to be, and how many hours we could stay out, that was it; there wasn't any point in saying ‘Well, hey, let's change that so instead of staying out two and a half hours, we can stay out four hours.’ Gee, the guys did the calculations and they said that's what you could do, so that's what we stuck with.”[233]

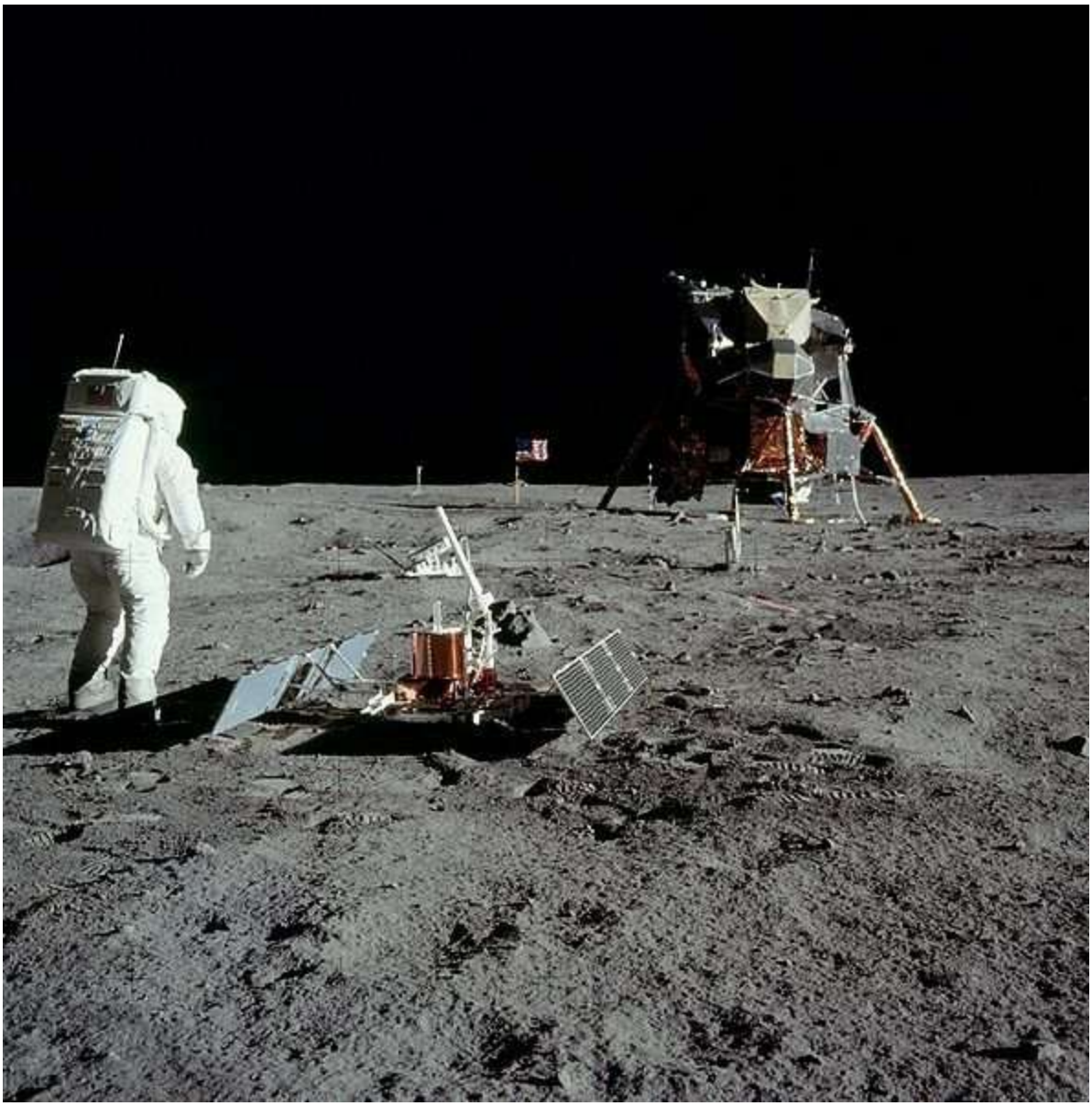
Aldrin's footprint on the Moon

Armstrong made sure to collect a Moon sample as soon as possible in case they had to quickly abort the mission and return to Collins and the *Columbia*. Now Aldrin focused on the two activities he had "crammed" the hardest for: the collection of geologically important samples and the use of a camera to document lunar surface exploration. In this he was successful, though with one twist. Aldrin only captured three photos of Armstrong on the surface of the Moon; and most of those photos did not show Armstrong straight-on. The reason for this omission lay with the time the astronauts spent on the Moon, two-and-a-half hours. They might have spent most of their time on the most difficult task of all: pounding the U.S. flag into the ground and unfurling it. [234]



Armstrong’s picture of Aldrin made sure to reflect the image of himself in Aldrin’s visor

The astronauts also took seismic readings of the surface, collected several pounds of rocks and samples, and left a plaque and other memorials at the landing site. The plaque read, “Here men from the planet Earth first set foot upon the Moon, July 1969 A.D. We came in peace for all mankind.”



Aldrin stands next to the Passive Seismic Experiment Package with the flag and the *Eagle* in the background

Armstrong and Aldrin entered the Ascent Stage with just enough time to take a phone call from President Richard M. Nixon, who told them:

> "Hello Neil and Buzz, I am talking to you by telephone from the Oval Room at the White House, and this certainly has to be the most historic telephone call ever made from the White House.
>
> I just can't tell you how proud we all are of what you have done. For every American this has to be the proudest day of our lives, and

for people all over the world I am sure that they, too, join with Americans in recognizing what an immense feat this is.

Because of what you have done the heavens have become a part of man's world, and as you talk to us from the Sea of Tranquility, it inspires us to redouble our efforts to bring peace and tranquility to earth.

For one priceless moment in the whole history of man all the people on this earth are truly one—one in their pride in what you have done and one in our prayers that you will return safely to earth."

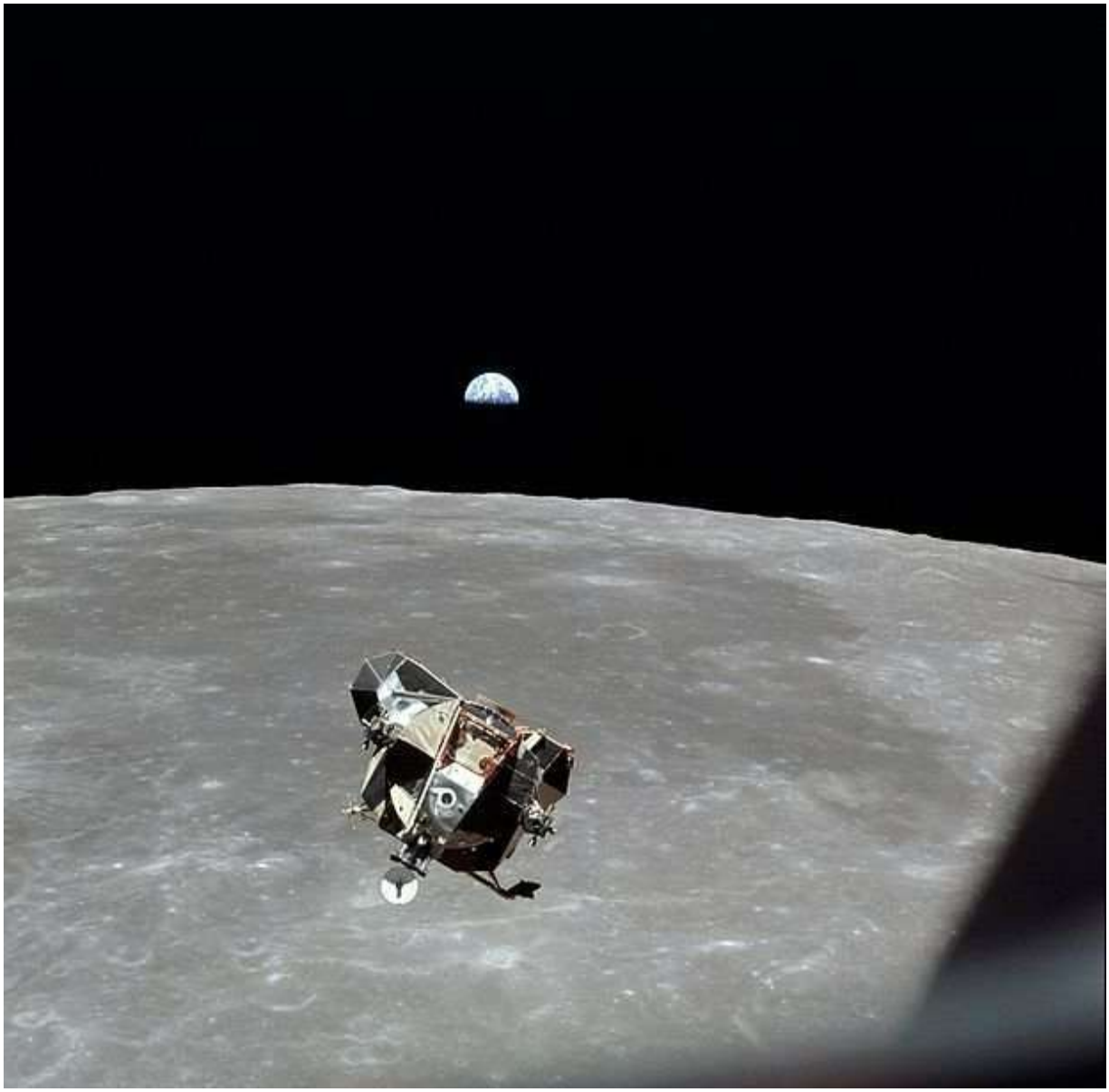
Still, one more problem remained that called for a solution: the arm switch on the ascent engine had broken off. With a ballpoint pen, Aldrin fixed the switch, and the Ascent Stage that engineers feared would not separate performed exactly as designed. The Eagle had "wings" again, and the astronauts rocketed into lunar orbit.[235]

While Armstrong and Aldrin had walked on the Moon, the *Columbia* had remained in orbit with Collins, the forgotten man in many ways. For every revolution he and *Columbia* made behind the far side of the Moon, he was truly the "loneliest man in the world." Ironically, he also belonged to another unique group of people as one of the only people to not witness Armstrong's first steps on the Moon. With a lot of time spent in solitude, Collins contemplated his surroundings and the influence of the experience. During every revolution, when he could finally see the Earth again, alone against the sea of black and stars, he pondered its position and state: "From space there is no hint of ruggedness to the [the Earth]; smooth as a billiard ball, it seem delicately poised on its circular journey around the Sun, and above all it seems fragile. Is the sea water clean enough to pour over your head, or is there a glaze of oil on its surface?...Is the riverbank a delight or an obscenity? The difference between a blue-and-white planet and a black-and-brown one is delicate indeed."[236]

As he stayed in orbit, he wrote, "I am alone now, truly alone, and absolutely isolated from any known life. I'm it...I feel this powerfully -- not as fear or loneliness -- but as awareness, anticipation, satisfaction,

confidence, almost exultation. I like the feeling."[237]

That said, meditations and connecting with the universe should not suggest that Collins had nothing to do in orbit or nothing to worry about. At one point, a problem developed with the coolant system on the *Columbia*, a situation that put Collins on edge. He solved that problem, but he still faced a bigger problem. The location of the *Eagle* on the Moon remained a mystery; and no one at NASA knew exactly where it had landed either. This could have meant trouble for the rendezvous between the two craft.



Picture of the *Eagle's* ascent stage heading toward *Columbia*

Since the Moon has no atmosphere, it was relatively easy for the *Eagle* to ascend without needing powerful rockets like the Saturn V. It only required the Ascent Stage with fuel propulsion engines to propel it back up to the *Columbia*, and once they linked back up, the ascent stage was jettisoned into orbit, eventually landing back on the Moon. The ascent was not without its issues either. One of the enduring images of the Apollo 11 mission was the planting of the American flag on the Moon's surface. Since the Moon has no atmosphere, there is no wind on the surface. Thus, the flag needed to be specially designed to remain completely unfurled. And with no wind on the surface, the intent was to have the flag stand forever. However, the mission's planners had overlooked one important detail. In one of the most unreported (and forgotten) aspects of the Apollo 11 mission, the ascent of the *Eagle* off the Moon's surface generated enough wind to inadvertently blow the flag over during liftoff. Aldrin watched the flag blow over and mentioned it during the ascent, making NASA aware of the issue. He later explained, "The ascent stage of the LM separated... I was concentrating on the computers, and Neil was studying the attitude indicator, but I looked up long enough to see the flag fall over." As a result, the astronauts on all subsequent Apollo missions made sure to plant the flag much farther away from the lunar module to avoid Apollo 11's mistake.

Collins could only look through the sextant and wait to sight the *Eagle*. He finally did, and after a complicated series of events to get the two ports to line up and hard dock, the latches clicked into place, and the *Eagle* and *Columbia* were reunited. The hatch was opened, and laughing and cheering began. Collins remembered the moment of reunion: "[I] grabbed Buzz by both ears and I was gonna kiss him on the forehead, I can remember that, and I got him to right about here and I said 'Eh, this is not a good thing to do somehow,' and I forgot, I clapped him on the back or shook his hand or something."[238]

The Moon's orbit is only a fraction of Earth's, so once the modules linked back up, the *Columbia* module was equipped with engines to propel it back toward Earth. The bigger concern for the return was that the modules had to reenter Earth's orbit at the proper angle to allow the planet to recapture it. Reentry into Earth's atmosphere subjects spacecrafts to temperatures of about 3,000 degrees Fahrenheit, so the module had an elaborate heat shield consisting of a mixture of dozens of panels, insulation and aluminum. A

failure in any part of the heat shield system would be fatal.

As Apollo 11 made its way back to Earth, the astronauts broadcast one last time on July 23 and gave thanks to everyone involved. Collins told the audience, “The Saturn V rocket which put us in orbit is an incredibly complicated piece of machinery, every piece of which worked flawlessly ... We have always had confidence that this equipment will work properly. All this is possible only through the blood, sweat, and tears of a number of a people ...All you see is the three of us, but beneath the surface are thousands and thousands of others, and to all of those, I would like to say, ‘Thank you very much.'"

Likewise, Aldrin told viewers, "This has been far more than three men on a mission to the Moon; more, still, than the efforts of a government and industry team; more, even, than the efforts of one nation. We feel that this stands as a symbol of the insatiable curiosity of all mankind to explore the unknown ... Personally, in reflecting on the events of the past several days, a verse from Psalms comes to mind. 'When I consider the heavens, the work of Thy fingers, the Moon and the stars, which Thou hast ordained; What is man that Thou art mindful of him?'"

Armstrong said, “'"The responsibility for this flight lies first with history and with the giants of science who have preceded this effort; next with the American people, who have, through their will, indicated their desire; next with four administrations and their Congresses, for implementing that will; and then, with the agency and industry teams that built our spacecraft, the Saturn, the Columbia, the Eagle, and the little EMU, the spacesuit and backpack that was our small spacecraft out on the lunar surface. We would like to give special thanks to all those Americans who built the spacecraft; who did the construction, design, the tests, and put their hearts and all their abilities into those craft. To those people tonight, we give a special thank you, and to all the other people that are listening and watching tonight, God bless you. Good night from Apollo 11."

Finally, it was time for the splashdown. The module had several “drogue parachutes,” used for decelerating fast moving objects, which were used at about 25,000 feet. Those parachutes slowed the module down to about 125 miles per hour. Another set of parachutes would then slow the module down

to about 20 miles per hour before it hit the water. Once the module splashed down, divers would deploy rafts to pick up the astronauts and anchor the module while a helicopter hovered overhead to collect everyone and everything. After being picked up, the returning astronauts would be quarantined for a period of time to study the effects the mission had on their bodies.

The splashdown of the *Columbia*

On July 24, Apollo 11 headed back to Earth and the splashdown in the Pacific Ocean, and the men would spend nearly a month in biological quarantine just to be careful. NASA had created an extensive but flawed process to protect the Earth from possible “Moon germs,” but in the end the men would return home. Of course, their lives were never the same, and all

three would leave NASA and the astronaut corps by the middle of the 1970s.

President Nixon visits the quarantined astronauts

The Aftermath of Apollo 11

Apollo 11 may be the most famous space mission in history, but NASA only intended for it to be the first of many manned missions to the Moon. Within four months of Apollo 11's mission, Apollo 12 sat on the launch pad, ready to go to the Moon for a more extended duration. Apollo 12 is largely forgotten today, sandwiched between the two most famous Apollo missions, but it was actually one of the most successful Apollo missions. Although Apollo 11 was an obvious success, the mission encountered some problems, particularly the *Eagle's* descent to the Moon's surface. Apollo 12's mission was designed to correct the kinks, while also staying on the Moon longer to conduct more sophisticated experiments.

Apollo 12 landed on the Moon's surface using cutting edge Doppler radar, and almost all of the lunar module's descent was done automatically, both improvements over Apollo 11. Apollo 12 made a near perfect landing in the "Ocean of Storms," chosen because NASA knew its earlier unmanned probe, Surveyor 3, had landed there two years earlier. NASA wanted Apollo 12's crew to collect the probe's parts and bring them back for analysis. Apollo 12's crew also took more samples, tested the Moon's magnetic field, and set up instruments that would continue to transmit data to Earth long after the mission.

Apollo 13 likely would have faded into relative obscurity had it successfully completed its mission, because that has largely been Apollo 14's fate. Apollo 14 successfully analyzed the Fra Mauro highlands and crater by spending over 30 hours on the Moon's surface. Apollo 14 also debuted the "Modularized Equipment Transporter," a fancy name for what was essentially the Moon's first wheelbarrow. It allowed the astronauts to lug nearly 100 pounds of equipment and samples around on the surface. One of these astronauts was Alan Shepard, Jr., who a decade earlier had become the first American in space aboard Freedom 7.

Apollo 14 may have used the first vehicle on the Moon, but Apollo 15 trumped it on July 30, 1971, when it landed on the Moon with the Moon's first rover. Unbeknownst to the United States, the Soviets had put a tiny rover aboard Mars 3 and launched it toward Mars just two months earlier, but

Apollo 15's Lunar Roving Vehicle was the first rover to land on another celestial body.

The Lunar Roving Vehicle became a staple of photographs and video shot during the final Apollo missions, and they are instantly recognizable today. The rover could travel about 10 miles per hour, allowing the crew to travel greater distances more easily in their bulky suits. Apollo 15's astronauts covered several miles on each rover, as did the astronauts of Apollo 16 and 17. All three rovers were left behind on the Moon's surface.

On the way back to Earth, Apollo 15 had the distinction of being the first mission to leave a satellite in Moon's orbit, allowing NASA to analyze the Moon's magnetic field, among other measurements. But Apollo 15 had been the fourth manned mission to land on the Moon in two years, and, at least to outside observers like President Nixon, each mission was accomplishing less noteworthy things. Except for the drama of Apollo 13, the missions never recaptured the original excitement of the first lunar landing mission, so it was only natural Apollo experienced a letdown. As the public's interest waned, missions were canceled, and the complete vision of the "Apollo Applications Project" would never be realized except for Skylab, the first and only American space station, which was fittingly launched by a Saturn V rocket. [239]

Less than a month after Apollo 15's mission, the Nixon Administration began pressuring NASA to pull the plug on the remaining Apollo missions. NASA had actually started doing the budget math nearly a year before Apollo 15 launched. In September 1970, NASA canceled two planned Apollo missions. But NASA was still able to launch Apollo 16 and Apollo 17 in 1972, with both missions placing an emphasis on the Moon's geology. Apollo 16 looked for volcanic activity among the Moon's highlands, while Apollo 17's crew included a professional geologist. On December 14, 1972, Apollo 17 Commander Eugene A. Cernan stepped off the Moon and back into the lunar module. No man has set foot on the Moon since.

Apollo 17 was the last Apollo mission. NASA ended up canceling three Apollo missions, designated today as Apollo 18, 19 and 20 even though two of those missions were to occur before Apollo 17. These missions were canceled due to budget cuts, and the materials for Apollo 20 were instead

used for the Skylab, America's first space station.

By the end of the Apollo program, NASA had already begun designing and developing the Space Shuttle Program, which would provide reusable vehicles for manned space travel and theoretically save money.

A number of reasons explain why the U.S. succeeded and sent astronauts to the Moon. Each of the men who flew on those missions represented the best parts of the nation's efforts and willingness to make the sacrifice. The success may have been best described by the then-director of NASA, James E. Webb. He left office before Apollo 11's triumph, but his captured the essence of what made the Apollo program such a uniquely American success:

> "The nations of the world, seeking a basis for their own futures, continually pass judgment of our ability as a nation to make decisions, to concentrate effort, to manage vast and complex technological programs in our interest. It is not too much to say that in many ways the viability of representative government and of the free enterprise system in a period of revolutionary changes based on science and technology is being tested in space... [Society has] reached a point where its progress and even its survival increasingly depend upon our ability to organize the complex and do the unusual. We cannot do these things except through large aggregations of resources and power. [It is] revolution from above."[240]

Some have pointed out that the success of Apollo 11 and the program as a whole is made all the more remarkable by the fact that changes in society over time might preclude similar results. As one group of British scientists commemorating the 40th anniversary noted, "It was carried out in a technically brilliant way with risks taken... that would be inconceivable in the risk-averse world of today... The Apollo programme is arguably the greatest technical achievement of mankind to date... nothing since Apollo has come close [to] the excitement that was generated by those astronauts - Armstrong, Aldrin and the 10 others who followed them."

Picture of the *Columbia* at the Smithsonian National Air & Space Museum

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